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PRESIDENTIAL ADDRESS

THE INFLUENCE OF FUNGI IN HUMAN AFFAIRS

LELAND SHANOR
University of Illinois, Urbana

LELAND SHANOR, *President*, 1955-1956

Some months ago when I casually mentioned to a colleague of mine that I was having to give some thought to an appropriate subject for a presidential address to the Academy, he made the comment that presidential addresses are always a problem. As he pointed out, however, on such an occasion it seems one is privileged to talk on almost any subject he wishes—even a moldy one. I decided, therefore, on a topic in the area of my own scientific work, one of a sufficiently general nature that it might include something possibly of interest to most members of the Academy.

Twenty years ago this coming June, I published my first paper dealing with that group of plants which I shall discuss; I have been working and contributing in this

area, both as an investigator and as a teacher, since that time. Therefore, it seemed that a brief review of some of the ways in which this particular group of organisms touches upon our lives, and has influenced the affairs of man, would be an appropriate topic.

This year the Illinois State Academy of Science will be concluding its 50th year as an organization. During these 50 years, all branches of science have made remarkable, and what might have been considered at the beginning of this period undreamed of, advances. This is certainly true of my own field of investigation, mycology. This field represents the special branch of plant science concerned with the study of molds, mildews, rusts, smuts, and other simple non-green plants which we include among the fungi. During this past half-century, we have learned much about controlling those fungi that cause plant and animal diseases, about those that spoil our foods and contaminate the products of our industry, and about those that we have been able to domesticate and control to produce useful products. It might be of interest at this time also, to recall some of the events in history that have been influenced by the activity of fungi. To many of you it may come somewhat as a surprise to know that the effects of fungal activity have caused spectacular emigrations of people, have affected the course of military campaigns, and in other ways have played a significant role in history. Fungi are becoming responsible for an increasingly longer list of products that contribute to a better way of life and are known to affect man in many more ways, and to a degree, not suspected 50 years ago. Before we consider any of these specific areas, however, perhaps it might be well to delay a moment to say a few words about how fungi live. For with this in mind, you may appreciate better some of the things that fungi do.

Since the fungi do not contain the green pigment, chlorophyll, that enables most of the other kinds of plants to manufacture their own food, fungi must obtain their food from existing food sources. Some of these fungi are parasites and derive their food from living plants or animals. Others are saprophytes, or saprobes, and obtain their food from dead plant or animal bodies or from products of plant or animal origin. Those that must utilize such complex substances as cellulose, lignin, proteins, and related materials must possess the ability to break these down to simpler substances which can be taken into the fungus body to supply the carbon, nitrogen, and additional elements needed for growth, reproduction, and other processes. Because their ability to do this is so remarkably diverse, especially for those that are saprophytes, fungi have been compared to a very efficient chemical factory. They produce a remarkable variety of enzymes which make them capable of breaking down a very diverse array of complex materials and which enable them to build up other complex substances from these. These activities are strictly chemical, carried out within or associated with the fungus itself. A prominent mycologist in this country, Dr. William H. Weston of Harvard University, has pointed out very pertinently that the fungi were

living very well in luxuriant carboniferous swamps on the DuPont slogan "Better things for Better Living through Chemistry" long before man himself had made his appearance on this earth.

At least some of the topics I have selected for comment here are well known to biologists generally, but others may be familiar to only a very few whose area of science is very closely related to my own. Science has become so diverse and complex that often we understand well the significance of only a small number of the areas most closely related to our own.

I should like now to consider some of the ways that fungi affect man adversely and then some ways in which they contribute to a better way of life for all of us.

Fungi are Harmful and Destructive

One very significant way in which fungi influence man adversely is as a cause of many different kinds of plant diseases. Plant diseases annually take a toll reaching into the billions of dollars in the U.S. alone. For man the problem of plant diseases is an old one, and one that is likely to remain in spite of advances which are being made in plant-disease control. In the course of history, there have been very significant epidemics of fungal plant diseases, some of which have occurred during our own lifetimes. Among these might be mentioned the chestnut blight disease which has, for all practical purposes, eliminated the American chestnut, recurring epidemics of stem rust of wheat, blight of oats, and others. Spreading now conspicuously in this area we have the Dutch elm disease, and appearing even more recently, the Wisconsin oak wilt.

In the very early literature, mention of crop diseases is found frequently. Of course, in ancient times any true conception of what caused these diseases was not suspected. The cause was looked upon as a deep, dark mystery, often being regarded as the visitation of some angry god. Grain rust, for example, was recognized as a devastating disease many hundreds of years ago. This same disease remains today one of the major problems of wheat growers. New resistant varieties of wheat are constantly being developed by plant breeders. Just about as rapidly the rust fungus produces new strains that are capable of attacking these new varieties. It sometimes seems to be a rather discouraging race, one in which the plant breeder never appears to be much in the lead. Loss of wheat from black stem rust in North America in 1916 exceeded 300,000,000 bushels. Almost 20 years later, in 1935, after it seemed that great progress had been made in eradicating this disease, a severe epidemic broke out on this continent and almost a quarter of the wheat crop was lost. In 1950 there was a near repetition of this disaster. You may be sure that the wheat rust fungus is a clever adversary. There are over 200 races of it known, and none of our varieties of wheat, even the most recently developed, are immune to all of them.

Probably one of the most devastating and spectacular plant disease epidemics in history was the late blight disease of potato during 1845 and 1846, caused by the fungus,

Phytophthora infestans. Although serious on the continent of Europe at that time, and to a lesser extent in America, it was in Ireland that the effects of the epidemic were most tragic. The potato represented almost the sole source of food for the impoverished Irish of the period. People on the continent and in America felt its effect much less because the diets of those living in these areas were much more diversified. When the blight of potato struck Ireland, the result was so devastating that almost a million people died of famine. Another million and a half emigrated to America. Ireland lost one-third of its population in the years between 1845 and 1860 because of this potato disease. This famine in Ireland affected history in another way, because its impact set the stage for the repeal of the corn laws in England and thus initiated a policy of free trade. The impact of this epidemic on English-Irish relations is still felt.

In the 20th century the potato blight fungus has also played an important, but perhaps relatively little recognized, part in history. In 1917, when Germany was dependent upon the potato as its principal war-time food crop, *Phytophothora infestans* again produced an epidemic that wiped out a third of the annual production in that country. Although reasonably effective control measures had been developed in the form of chemical fungus-killing materials that could be sprayed or dusted on the potato plant to protect it from the cause of the disease, the necessities of war required that materials, such as copper, which might be employed in fungicides, be used for immediately critical military demands. The late blight fungus was on hand for just such an opportunity and the result is now a matter of history. The resulting reduction in the already short food supply of Germany contributed very significantly to the breakdown in morale and physical endurance that led to the ultimate defeat of the German army.

The list of plant diseases caused by fungi is a long one, but the effects of the two just mentioned have been among those most significant. Many other plant diseases are of lesser importance in the affairs of man than these two, but each year the total destruction of food plants, fiber plants, timber, and other crops is staggering. New fungi parasitic on plants are being reported every year, and many plants have not been searched as yet for their fungal parasites. Each year it seems that new and more virulent strains of some of the previously less significant pathogens make their appearance. Although we have been combating plant - disease - producing organisms for a long time and have made progress, much remains to be done before we can assume we have succeeded satisfactorily in this continuing conflict between man and the fungi that seriously damage his crops.

Although the fungi causing diseases in man have not had the same impact upon history as some other kinds of pathogens which cause diseases, for example bubonic plague and cholera, their effect on the individual is, nevertheless, significant and a large percentage of the population, at one time or another, may suffer from a fungal infection. Athlete's foot and ring worm represent two of the most widespread of the human diseases caused by fungi.

These are superficial mycoses and can be reasonably controlled with a little attention to proper medication and preventive measures. There are some deep-seated fungal diseases, however, affecting such organs as the lungs, spleen, or other vital organs, which are very difficult to combat and which are often fatal. The mid-west seems to be the focal point for one of these, a disease known as histoplasmosis. The arid south-west is the endemic area for another one of the deep mycoses, one known by a number of names such as "desert rheumatism", "valley fever", "California disease", and the more technical designation, coccidiomycosis.

During World War II, when our armed forces were widely dispersed in the tropical regions of the earth, particularly in the western Pacific, fungal infections among troops became a real problem. The superficial skin infecting organisms, common but usually producing relatively mild symptoms in temperate regions, seemed to be stimulated by the moist, hot climate of the tropics. Infections caused by many of the same group of fungi responsible for athlete's foot and related troubles produced symptoms in the tropics well portrayed by such picturesque names as "jungle rot", "jungle foot", and other similarly enlightening epithets which bear testimony to their severity. Fungal infections of man generally are regarded as occurring more frequently and as being more severe in tropical regions than in temperate.

There are many kinds of fungal diseases of man that are widely distributed over the world, but we will dwell no longer on these ways in which the fungi affect man, except to call attention briefly to one other. This one is quite different but none the less distressing—as a cause of allergy. Those of you who have had scratch tests for hay fever or other forms of allergic reaction may recall such names as *Alternaria, Aspergillus, Hormodendron,* and *Rhizopus,* on the list of things for which you were tested. These represent the names of just a few genera of the fungi now known to include species capable of producing allergies in some people.

The adverse effects of fungi in the affairs of man are not limited to those caused by fungi that damage his crop plants, that affect his domesticated animals, or which invade his own body. The purely saprophytic fungi create many problems, also. The unprotected wood of houses and boats is just as susceptible to fungal attack as was that wood on the floor of the carboniferous jungle or as is that on the floor of our forests today. When the fleets of the world were made up largely of wooden ships, the fungi repeatedly contributed importantly to the outcome of conflicts. In the American Revolution, for example, fungi were on our side at a very critical moment. In the Battle of Yorktown the outcome might have been quite different had not fungi contributed their part in preventing supplies from reaching Cornwallis in time. These supplies were delayed because the ships bringing them were forced to refit at New York before proceeding southward. The fungus-rotted timbers of this British fleet were no match for a crippling storm encountered at sea. School boys and girls know that Cornwallis was forced to surrender, but history books do not record the fact that it

probably was just as much the contribution of the fungi as an ally to our cause that brought about this defeat as the contribution of the strictly military operations.

Even as recently as World War II, modern metal vessels were found to be vulnerable to fungal attack, just as were their wooden predecessors, but in a very different way. Instead of masts, spars, and holds being weakened by fungi, this time it was electrical installations, such as transfer switches, telephone systems, gun directors, and other similar equipment that became affected. The vulnerable spot was found to be generally the normally untreated electrical insulation. This material, without some fungus-inhibiting substance incorporated in it, proved to be a very good substrate for the growth of fungi. The fungi this time affected naval efficiency by disrupting electrical currents and interfering with communications and other operations.

Many items of equipment going into war theaters in World War II were found to be initially very susceptible to fungal attack. Rope, canvas, cotton, and woolen fabrics, and many other items of equipment for the Army, the Navy, the Air Force, and the Marines were discovered to be inadequately protected from fungal attack, both while enroute to the Pacific theater and when put into service. A tent pitched in New Guinea in the early part of the war would withstand deterioration by fungi and weather for only a few weeks. Such a short useful life not only created a major problem from the standpoint of service, but also placed a tremendous burden on our ability to deliver adequate supplies to our fighting forces. To provide protection from fungi, new uses were found for old fungicides and new fungicides which could be incorporated into materials going into the various areas of military operations were developed. Before many months the same kind of tent that had previously lasted but a few weeks in New Guinea, but now treated, had its useful life extended to many months. The danger of possible fungal deterioration of other equipment was reduced also. New synthetic materials not subject to fungal attacks were developed. The war in the Pacific might have been lost in the early days of the conflict had we not been able to recover quickly from the unexpected blow dealt us by the fungi. It is now a standard practice to, as far as possible, either fungus-proof military equipment or use materials that are immune to fungal attack.

The examples just provided would lead one to believe that most of the activities of fungi in the affairs of man are destructive, and to think of the fungi as only a sinister and treacherous lot. This is not at all the case. Man derives many benefits from various fungal activities, and I should like now to comment briefly upon some of these. I shall limit my discussion to a few of the most important of the contributions which fungi are known to make to improve our enjoyment of living, to provide better health, and to make possible a longer life.

Fungi are Useful

The constant volume of advertising through all media of communication cannot but make one aware of

the magnitude of that part of the fermentation industry devoted to the production of alcoholic beverages. The production of alcoholic beverages and industrial alcohol, along with by-products of this fermentation, represents a large and significant area of industrial enterprise. The brewing of alcoholic beverages is not a development of modern times; its present importance has been brought about by a refinement of techniques, better control of processes, and the necessity for production on a much larger scale than was possible in ancient time. Societies dating at least as far back as 4,000 to 6,000 years were known to make use of some kind of fermented beverage, derived either from fermented fruit, fermented milk, fermented grain, or from some other suitable raw material. What brought about the fermentation was not demonstrated conclusively until within the last 150 years, and the many refinements for the control of the process are largely developments of the last half-century. Under modern fermentation methods, not only are the yeast fungi cultivated for the production of alcohol, but they represent a rich source of vitamins, a rich source of proteins that may be used as a supplement for animal foods and for human consumption, and a source of additional materials.

The production of still other useful products by fermentation in which fungi other than yeasts are used has been a major development of the past 50 years. Certain of the organic acids and the antibiotics represent the two main categories to which such products belong.

Early in the second decade of this century it was discovered that the black mold, *Aspergillus niger,* possessed a high productive capacity for certain organic acids, such as citric, when grown under certain conditions. This has led to the industrial production of citric acid by molds which has largely replaced its extraction from citrus fruits. Prior to this development, citric acid was obtained principally from Italy and we imported many tons of it into the United States. Within the next decade after the potential capacity for citric acid production by the black *Aspergillus* was demonstrated, the United States became self-sufficient for this material and, as a matter of fact, even became an exporter. Citric acid has many uses in foods, in drugs, in confections, in beverages, and in other ways. Other useful organic acids are also obtained from a fermentation in which this same mold and related ones are cultivated under controlled conditions.

Of the many additional discoveries of products obtained from fungi cultivated under industrial conditions, perhaps none have been more spectacular or have contributed as much to human comfort in the conflict of man with his ailments as has the discovery of penicillin. This has been a rather recent development, for the therapeutic value of penicillin was demonstrated as short a time ago as 1940. The discovery and development of all of the other useful antibiotics have occurred since that time. The story of the development of penicillin as an important treatment for many kinds of infections has been so widely publicized I feel certain that all of you have some familiarity with it. Perhaps few of you are aware, however, that it was here in Illinois at the Northern

Regional Laboratory in Peoria that some of the most significant research and useful discoveries connected with the development of penicillin in this country took place. The highest yielding strain of the penicillin-producing mold now used, *Penicillium chrysogenum,* was isolated at the Peoria Laboratory from a moldy cantaloupe obtained from a Peoria market. Mutant strains derived from this original one obtained from a natural source have been produced by x-ray and ultra-violet irradiation which now produce yields of penicillin many times that of the naturally occurring strain obtained from the cantaloupe, or from the species originally used by Dr. Alexander Fleming who discovered and named this antibiotic. The rapid and spectacular development of antibiotics in medicine since the discovery of penicillin by Fleming in 1928, and proof of its therapeutic usefulness by Chain, Florey and co-workers in 1940, probably has left the impression with many that antibiotics had their beginning with Fleming's discovery. It is certainly true that the modern development of this field begins with these discoveries, but antibiosis as a phenomenon in nature had been recognized by mycologists and microbiologists for about as long as they have been culturing microorganisms. The therapeutic value of mold cultures for treatment of certain superficial infections dates back many centuries. Indeed at least as early as 1000 B.C., the Chinese are known to have used molded soy products to combat infections of the skin. It has been reported also that primitive Indians of the western hemisphere employed fungi in the treatment of wounds that had become infected.

Although there are other products formed by fungi that might be mentioned in connection with their contribution to medicine, I shall refer only to one more. The chemical activity of certain molds under highly controlled conditions very recently was discovered capable of bringing about the synthesis of a group of medically important materials much more efficiently than was possible by strictly chemical synthesis. These important products that can be produced by mold activity are cortisone and cortisone derivatives, used for the treatment of rheumatism and arthritis, skin disorders, intractable asthma, certain infections of the eye, and other inflammations. Cortisone was originally obtained from animal bile in exceedingly small amounts. The beneficial effect to be derived from the use of cortisone in treatment of arthritis was discovered in 1948. The convenience of production of cortisone and related drugs by using certain fungi to bring about desired stages in the manufacture of them, first revealed in a patent application in 1950, is a significant new development in which fungi are contributing in a previously undreamed of way to a healthier and happier life for many people.

Although many fungi such as the truffles, mushrooms, morels, and some other fleshy forms have long been recognized as prize delicacies, the yeasts seem likely to become the most significant of all as food fungi. Already the nutritive value of yeasts is widely recognized by their inclusion in many foods of man and feed for his domesticated animals. As a

potential source of protein in the diet of large populations of the world, the possible contribution of yeasts is only beginning to be realized. There are many areas on the globe where an adequate supply of protein from the usual source, meat, is not available. This is because either adverse environmental conditions affect the practical production of animals for meat or because of religious bias against the eating of meat. Yeasts may, in the years ahead, contribute materially to the solution of this problem. Certain yeasts are high in protein. They can utilize cheap and widely available carbohydrates to form proteins and fats. They can be cultivated readily and under controlled conditions. Yeasts are not animals and, therefore, would not be subject to religious bias in areas where eating of meat is forbidden. The installations necessary to produce food yeast need not require any of the best agricultural land now under cultivation. To be sure, there are many problems that remain to be solved before large-scale production becomes a reality, but utilization of food yeasts as a protein source represents one way in which the dietary needs of an expanding population, or of an already over-populated area, might be met or improved.

The dairy industry makes good use of some fungi for producing the blue cheeses such as Roquefort, Stilton, Gorgonzola, etc., and the soft cheeses of the Camembert type. For centuries it has been assumed that the production of such cheeses was dependent upon special conditions found in certain famous, cheese-ripening caves in Europe. At the turn of the 20th century, an able young American mycologist employed by the Department of Agriculture, Dr. Charles Thom, demonstrated that for each of these types of cheese one specific mold, from among all of those kinds that might be present, was responsible for imparting the specific flavor and texture to each of these cheeses. The molds were isolated in pure culture and inoculated into properly prepared curd. This, when aged under necessary conditions of temperature and moisture, produced a product as good as, or even better than, the cheese produced in caves. Control was easier. Thus was born our domestic production of these cheeses.

Before leaving this subject, it should be mentioned also that fungi are very important as producers of vitamins and of enzymes.

It can be seen from even this brief survey that fungi have played, and are continuing to play, an important part in the affairs of man. The prospect for their contributing even more to an increasingly healthful, more enjoyable, and longer life in the years ahead is bright. We have just begun to discover the potentialities of the fungi.

It is obvious, too, that the fungi always will be with us. As a mycologist friend of mine, Dr. J. C. Gilman of Iowa State College, pointed out a decade ago, even the Bible promises no escape from them in the hereafter. The 20th verse of the 6th chapter of the Book of Matthew advises, "But lay up for yourselves treasures in heaven, where neither moth nor rust doth corrupt, . . ." This statement would seem to indicate that insects and corrosion are absent in heaven, but no mention is made of the fungi.

PROGRAM FOR THE 49th ANNUAL MEETING
PAPERS PRESENTED

AQUATIC BIOLOGY

WILLIAM C. STARRETT, *Chairman*
Illinois Natural History Survey, Havana

*Fishes of Sugar Creek, a Tributary of the Saline River. Gerald Gunning and William M. Lewis, Southern Illinois University, Carbondale.

Stocking of Fish-eating Birds on Farm Ponds. Leonard Durham, Eastern Illinois State College, Charleston.

Effects of Drought Conditions on the Fish and Bottom Fauna of a Small Oxbow. Andreas A. Paloumpis, Iowa State College, Ames, Iowa.

Smallmouth Bass in Warm-water Ponds. George W. Bennett, Illinois Natural History Survey, Urbana.

Plankton Studies of Lake Michigan. II. Thirty Years of Plankton Data Collected at Chicago, Illinois. Kenneth E. Damann, Eastern Illinois State College, Charleston.

An Investigation of Dissolved Oxygen Concentrations of Three Illinois River Bottomland Lakes. Harry O. Jackson, Illinois State Normal University, Normal.

*Factors Influencing Excessive Flows of Coal Strip Mine Effluents. John D. Parsons, Western Illinois State College, Macomb.

Limnology of the Middle Mississippi River and Adjacent Waters. III. Factors Affecting Primary Productivity, 1955. Troy C. Dorris, Quincy College, Quincy.

Age and Rate of Growth of the Yellow Bass in Reelfoot Lake, Tennessee, for 1939 and 1955. Robert J. Schoffman, Spalding Institute, Peoria.

*Boat Fishermen's Catch at Crab Orchard Lake, Murphysboro Lake, and Horseshoe Lake During 1955. William M. Lewis, Bob Brantley, and Ronald Newton, Southern Illinois University, Carbondale, and State Department of Conservation, Springfield.

A Limnological Survey of Rock Run Creek, Stephenson County, 1954 and 1955. Vernon E. Bestes, Lincoln Junior High School, Rockford.

ARCHAEOLOGY AND ANTHROPOLOGY

WILLIAM H. FARLEY, *Chairman*
Harrisburg, Illinois

Biological Hazards of Prehistoric American Indians. C. C. Burford, 907 S. Orchard, Urbana.

Illinois Archaeological Survey. John C. McGregor, University of Illinois, Urbana.

Seminole Indians of Florida. Irvin Peithman, Southern Illinois University, Carbondale.

Archaeology of Western Illinois. Don Dickson, Dickson Mounds State Park, and James R. Reed, Quincy.

Unusual Finds in Hardin County. Melvin Fowler, State Museum, Springfield.

Explanation of Surplus Specimens of Indian Relics. Members to bring gift specimens for students.

Prehistoric Mexico. Byron W. Knoblock, Quincy.

* Published in this volume.

BOTANY

R. MAURICE MYERS, *Chairman*
Western Illinois State College, Macomb

Elm Tree Disease, Diagnosis and Treatment. Howard D. Salens, Flax Institute of America, Chicago.

Volvariella in North America and the status of V. plumulosa. Robert L. Shaffer, University of Chicago, Chicago.

Botanica philatelica. Loring M. Jones, DeKalb Agricultural Association, Inc., DeKalb.

*The Effect of Substrate Hydrogen Peroxide on the Growth of Boron Deficient Plants. Haling J. Presley, University of Illinois, Navy Pier, Chicago, and Wayne J. McIlrath, University of Chicago, Chicago.

The Effects of Variation in Boron Nutrition on the Anatomy of the Cotton Plant. Barbara F. Palser, University of Chicago, Chicago.

*An Expedient Method of Obtaining Mitotic Figures in Alisma (Dill.) L. Seedlings. James E. Love, Southern Illinois University, Carbondale.

A Comparison of Mature Wood Anatomy of Ampelothamnus phillyreifolius and Four Species of the Genus Pieris. Jean M. Voegeli, Rockford College, Rockford.

Histological and Chemical Changes Accompanying Cotton Stem Intumescences Induced by Flooding. Wayne J. McIlrath, University of Chicago, Chicago.

A Hillside Marsh, Tippecanoe County, Indiana. Donald A. Larson, University of Illinois, Champaign, and Franklin Buser, East Stroudsburg College, East Stroudsburg, Pennsylvania.

Radial Growth of Beech in Central Ohio During 1954-55. Harold C. Fritts, Eastern Illinois State College, Charleston.

*The Gravel Hill Prairie of Rock River Valley. Egbert W. Fell, Rockford. By title only.

*Illinois Myxomycetes, Richard K. Benjamin, Rancho Santa Ana Botanic Garden, Claremont, California.

CHEMISTRY

Section A

CHARLES D. PROCTOR, *Chairman*
Loyola University, Chicago

The Benzenoid Inhibition of the Kolbe Electrolysis: An Electro-steric Phenomenon? G. W. Thiessen, Monmouth College, Monmouth.

*Polarography of Sulfhydryl-Disulfide Systems. Hugh M. Millen and Leon Gershbein. Illinois Institute of Technology, Chicago.

A Study of the Organ Distribution of Adenosinetriphosphate. Charles D. Proctor, John Rebar, Jr., and Blanche Tigerman Rebar, Loyola University, Chicago.

A Study of Digitoxin Effects on Cholinesterase from Dog Heart Muscle. Blanche Tigerman Rebar, John Rebar, Jr., and Charles D. Proctor, Loyola University, Chicago.

*Some Problems in the Synthesis of an Antimalarial Intermediate. Sister Mary Marina, Mundelein College, Chicago.

A Study of Digitoxin Effects on Adenosinetriphosphatase from Dog Heart Muscle. John Rebar, Jr., Blanche Tigerman Rebar, and Charles D. Proctor, Loyola University, Chicago.

A Polarographic Determination of Hydrogen Sulfide. J. A. Gylys and Charles D. Proctor, Loyola University, Chicago.

Stimulating Interest in Chemistry. Paul E. Smith, Urbana High School, Urbana.

Section B

J. V. KARABINOS, *Presiding*
Blockson Chemical Company, Joliet

Desoxyribonuclease Control. Frank O. Green, Wheaton College, Wheaton.
Sequestration of Aldonic Acids in Alkaline Solution. J. V. Karabinos and E. J. Quinn, Blockson Chemical Company, Joliet.
*Reaction of Antimony Chlorides with Ethylene Oxide. A. T. Ballun and J. V. Karabinos, Blockson Chemical Company, Joliet.
Studies on Carboxymethylcellulose. E. J. Quinn and J. V. Karabinos, Blockson Chemical Company, Joliet.
Radicagen: A New Concept in Compound Classification. Calvin P. Midgley, Lake Villa and Antioch High School, Antioch.
Coordination Compounds and General Chemistry. Sister Mary Martinette, Mundelein College, Chicago.
The Effect of Several Levels of Sodium in Rations Fed to Baby Pigs. John W. Yusken and Elwood F. Reber, University of Illinois, Urbana.
Attempted Synthesis of 3-aza-3-alkyl (3, 3, 1) nonan-9-ones. Carl Weatherbee, Donald Winter, and William Adcock, Millikin University, Decatur.

GEOGRAPHY

ROBERT L. CARMIN, *Chairman*
University of Illinois, Urbana

Non-Europeans in Illinois. John H. Garland, University of Illinois, Urbana.
*Areal Differentiation in the Growth of Population in the Surburban Municipalities of Chicago. Clyde F. Kohn, Northwestern University, Evanston.
*The Urbanization of Illinois, 1870-1950. Jerome D. Fellmann, University of Illinois, Urbana.
*Patterns of Agricultural Change in Illinois. Howard G. Roepke, University of I linois, Urbana.
Frequency Studies of Cloud Types and Precipitation Amounts in Illinois. Stanley Changnon, Jr. and Floyd A. Huff, Illinois State Water Survey, Urbana.
The Use of Statistical Profiles in Determining Regional Boundaries. Edwin N. Thomas, Northwestern University, Evanston.
Climatic Aspects of Soviet Plans to Increase Agricultural Production. Chauncy D. Harris, University of Chicago, Chicago.
Reasons for the Arid Zone in Northeastern Venezuela. Charles S. Alexander, University of Illinois, Urbana.
*Rainfall on Jamaica. James A. Taylor, University of Illinois, Urbana.
Geography: Not Primarily a Study of Area Differences. Robert A. Harper, Southern Illinois University, Carbondale.
Large Scale Commercial Cattle Feeding in Northern Illinois. William Stroebel, University of Chicago, Chicago. By title only.
Andean Scenes. Reece A. Jones, Western Illinois State College, Macomb. By title only.

GEOLOGY

GEORGE W. WHITE, *Chairman*
University of Illinois, Urbana

*Intrusion of Till into Jointed Limestone, Fairmount Quarry, Illinois. Don U. Deere and Paul R. Shaffer, University of Illinois, Urbana.
*The Subsurface Glacial Geology at Proposed Effingham Damsite. George E. Ekblaw, Illinois State Geological Survey, Urbana.
Revision of the Algonquin Stage of the Great Lakes. Jack L. Hough, University of Illinois, Urbana.
Igneous Intrusive Rocks in Illinois. Kenneth E. Clegg and James C. Bradbury, Illinois State Geological Survey, Urbana.

*A Pseudo-Ring Dike, Mt. Desert Island, Maine. Carleton A. Chapman. University of Illinois, Urbana.

*Clastic Strata in Some Pennsylvania Limestones. Meredith E. Ostrom, Illinois State Geological Survey, Urbana.

The Chemical Composition and Microstructure of the Neurodontiformes. F. H. T. Rhodes and Paul S. Wingard, University of Illinois, Urbana.

PHYSICS

IRVIN L. SPARKS, *Chairman*
Eastern Illinois State College, Charleston

*A New Method for Getting Motion Through the Walls of Sealed Enclosures. Arthur L. Riche, Micro Switch, Freeport.

*Acoustic Problems of the Flute. Howard C. Roberts, University of Illinois, Urbana.

A Nuclear Decay Scheme. Robert C. Waddell, Eastern Illinois State College, Charleston.

Some Recent Results on Flux and Angular Distribution for Heavy Primary Cosmic Rays. Otis B. Young and T. S. Yoon, Southern Illinois University, Carbondale.

SCIENCE EDUCATION, PSYCHOLOGY AND SOCIAL SCIENCE

ROBERT A. BULLINGTON, *Chairman*
Northern Illinois State College, DeKalb

*A Philosophy of Science Engineering Education. George G. Lamb, Northwestern University, Evanston.

A School Camping and Camping Education Program. John W. Klotz, Concordia Teachers College, River Forest.

*Writing the Scientific Paper. James S. Ayars, Illinois Natural History Survey, Urbana.

Demand for Teachers in Science and Related Fields. Martin H. Bartels, Northern Illinois State College, DeKalb.

Plans and Progress in the Revision of the Illinois Curriculum Guide for Elementary Science. Clyde M. Brown, Southern Illinois University, Carbondale.

What Type Experiments in Physical Science for Elementary Education Majors? Allan Dale Weaver, Northern Illinois State College, DeKalb.

Photography in the Science Classroom. Charles L. Haggard, Vincennes University, Vincennes, Indiana.

The Speech Amplification Index: A Method of Expressing Loss in Hearing That Can Be Understood by Laymen. Ralph Martin McGrath, La Grange.

Instruments and Devices for Teaching Reading. Murray Lincoln Miller, Illinois State Normal University, Normal.

ZOOLOGY

Section A

MILTON W. SANDERSON, *Chairman*
State Natural History Survey, Urbana

Footedness in Domestic Pigeons. Harvey I. Fisher, Southern Illinois University, Carbondale.

Inheritance of Taste for Sodium Benzoate in the Ferguson Clan. Max B. Ferguson, Eastern Illinois State College, Charleston.

*The Average Number of Illinois Species per Genus of a Few Animal Classes. Philip W. Smith, State Natural History Survey, Urbana.

Studies on the Posterior Gill Apparatus of the Naid, Aulophorus furcatus (Annelida). Robert H. Foulkes, Northern Illinois State College, DeKalb.

The Spread of Catorhintha mendica (Stal), (Coreidae, Hemiptera). Walter V. Balduf, University of Illinois, Urbana.

The Location of the Types and Paratypes of Molluscan Species Described by the Late Frank Collins Baker. Dorothea S. Franzen, Illinois Wesleyan University, Bloomington.

*Thrips (Thysanoptera) New to Illinois. Lewis J. Stannard, Jr., State Natural History Survey, Urbana.

Section B WALTER M. SCRUGGS, *Presiding*
Eastern Illinois State College, Charleston

Some Aspects of Nematode Parasitism in Captive Animals. B. J. Jaskoski, Loyola University, Chicago.

Screening Tests of Some Organic Phosphorus Compounds Against Horse Strongyle Larvae in vitro. Norman D. Levine and Sidney Kantor, University of Illinois, Urbana.

*Cysticercus fasciolaris and Capillaria hepatica in the Wild Rat. Wayne W. Wantland, Harold M. Kemple, and Kenneth E. Dye, Illinois Wesleyan University, Bloomington.

The Development of Mixed Cell and Spindle Cell Sarcoma in White Rats Infected with Cysticercus fasciolaris. Wayne W. Wantland, George R. Beers, and Kenneth E. Dye, Illinois Wesleyan University, Bloomington.

Anticoagulants for Turtle Blood. Harold M. Kaplan, Southern Illinois University, Carbondale.

Intissue Maturation of the Lymphocyte with Special Reference to the Flavanoid Catalysis. Walter Shriner, Springfield.

*The Effect of Cardiac Glycosides on the Potassium Content of Skeletal Muscle of Rana pipiens. Joab K. Aronson, Roosevelt University, Chicago.

COLLEGIATE SECTION

ROBERT A. EVERS, *Coordinator*
State Natural History Survey, Urbana

Section A FRANCIS SCHIMA, *Chairman*
St. Procopius College, Lisle

The Construction and Testing of a Laboratory Model Fermenter. Marvin J. Starzyk, Loyola University, Chicago.

Art and Geometry. Margaret Murphy, Rosary College, River Forest.

*The Suburbanization of a Rural Trading Center. Judith Oppenheim, Northwestern University, Evanston.

*A Study of the Unsaponifiable Fractions of Cooking Oils. Dolores Torres and Toni Trinchese, College of St. Francis, Joliet.

*Electrical Conductivity of the Isomeric Butyl Bromides. Robert Hemwall and Richard Henry, Monmouth College, Monmouth.

Electrical Properties of Indium Oxide. Louis Van Bessen, Southern Illinois University, Carbondale.

Section B DALE DEGEETER, *Presiding*
St. Procopius College, Lisle

Molting, Growth, and Differentiation in the Class Insecta. Thomas Back, St. Procopius College, Lisle.

The Antibiotic Spectrum and Activity of a Spore-forming Bacterium. Marilyn Weiland, Loyola University, Chicago.

Congenital Anomalies of the Human Uterus. Robert R. Merwick, St. Procopius College, Lisle.

The Effect of Radiation on Serratia marcescens. Ann Prock, College of St. Francis, Joliet.

A Comparative Microscopic Study of Vertebrate Blood. Edell Denault, College of St. Francis, Joliet.

*Bacteria We Drink. Frank Lipousky, Eastern Illinois State College, Charleston.

Fungus Infections of the Glabrous Skin. Nanette Thrift, Monmouth College, Monmouth.

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AQUATIC BIOLOGY

THE FISH POPULATION OF SUGAR CREEK, ILLINOIS

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INTRODUCTION

Sugar Creek is a picturesque tributary of the south fork of the Saline River, into which it empties northeast of Creal Springs, Williamson County, Illinois. It is approximately 15 miles long.

This study of the fish population of Sugar Creek is a facet of an overall study which has as its purpose the determination of species composition and distribution of the fish fauna of southern Illinois.

Seven collecting stations were set up along the 15 miles of stream, station number 1 being in the headwaters and number 7 located near the confluence of Sugar Creek and the south fork of the Saline River. Samples of fishes were taken by an electro-fishing apparatus described by Lewis and Elder (1953) and a 0.25-inch knot seine. A sample at a particular station consisted of the majority of the fishes found in a pool and connected riffles. All collections were preserved in 10% formalin and returned to the laboratory for study. The majority of the collections was made during the months of July and August, 1954.

This was a cooperative study between the Division of Fisheries, Illinois Department of Conservation, and the Cooperative Fisheries Laboratory and the Department of Zoology of Southern Illinois University.

COLLECTING STATIONS

Only the headwater stations of Sugar Creek exhibited distinct riffle-pool development. Pools ranged in length from 30 to 75 feet with widths of 15 to 20 feet and depths of 3 to 5 feet. Riffles ranged in length from 50 to 75 feet with widths of 15 to 20 feet and depths of 6 to 12 inches. Although the middle and lower extents of the stream did not exhibit distinct riffle-pool development, deep and shallow areas were recognizable. The deep areas ranged in length from 30 to 300 feet with a width of 15 to 35 feet and a depth of 2 to 8 feet. The shallows ranged in length from 50 to 75 feet with a width of 15 to 20 feet and a depth approximating one foot.

A Bristol recording thermometer was used to determine simultaneously the air and water temperatures over a period of one week. Water temperatures from June 27 to July 5, 1955, ranged from 21° to 29° C., at which time the air temperatures ranged from 11° to 29° C. These data indicated that the water temperature approximated the average air temperature. On this basis, it was assumed that no quantity of spring water entered the stream. The water of Sugar Creek was crystal clear except during periods of flooding or heavy spring rains. Stream flow approximated 7.2 cubic feet per second.

The bottoms of the four uppermost stations consisted of bedrock and gravel, whereas those of the lowermost stations consisted of bedrock overlaid by mud. The banks of most stations were of mud and relatively steep; however, some were bounded by large rock exposures. Signs of flooding were evident along the entire length of the stream, and log jams were prevalent in some areas. Approximately 60% of the watershed consisted of cultivated fields and the remaining 40% consisted mainly of woodland.

Annotated List of Species

Following is a list of the fishes collected during the survey. Annotations include distribution within the stream, habitat conditions, and abundance expressed as percent of the total number of fish taken. In general, scientific names are after Hubbs and Lagler (1949).

Family Petromyzontidae

Entosphenus lamottenii (LeSueur), American brook lamprey. 0.1%—One adult male.

Family Catostomidae

Erimyzon oblongus claviformis (Girard), creek chubsucker. 5.9%. Young-of-the-year numerous at practically all stations. Adults taken only in deeper pools.

Catostomus commersonnii commersonii (Lacépéde), common white sucker. 3.1%—All specimens taken in headwaters over gravel bottom.

Moxostoma erythrurum (Rafinesque), golden redhorse. 1.3%—Ten specimens taken in middle segment of stream.

Minytrema melanops (Rafinesque), spotted sucker. 0.6%—Five specimens taken in middle reaches of stream.

Family Cyprinidae

Notropis umbratilis cyanocephalus (Copeland), redfin shiner. 35.3% — Young-of-the-year, sub-adults, and adults were distributed rather evenly throughout entire stream.

Pimephales notatus (Rafinesque), bluntnose minnow. 13.2%—Young-of-the-year, sub-adults, and adults distributed rather evenly throughout the entire stream.

Semotilus atromaculatus atromaculatus (Mitchill), creek chub. 5.8%—Forty-six creek chubs taken in headwaters over gravel bottom.

Ceratichthys perspicuus (Girard), bullhead minnow. 0.9%—Seven specimens taken over bedrock in headwaters.

Family Ameiuridae

Ameiurus natalis natalis (LeSueur), yellow bullhead. 0.9%—Seven specimens.

Ameiurus melas melas (Rafinesque), black bullhead. 0.7%—Only young-of-the-year taken.

Family Esocidae

Esox vermiculatus LeSueur, mud pickerel. 0.7% — Of six adults taken, five in headwaters.

Family Cyprinodontidae

Fundulus notatus (Rafinesque), blackstripe topminnow. 6.8% — Collected at all stations.

Family Aphredoderidae

Aphredoderus sayanus gibbosus (LeSueur), pirateperch. 4.3%—Collected at all stations.

Family Percidae

Boleosoma nigrum nigrum (Rafinesque), Johnny darter. 0.9%—Seven specimens taken over gravel and bedrock.

Poecilichthys caeruleus (Storer), rainbow darter. 0.7%—Six specimens taken from three uppermost stations over gravel and bedrock bottoms.

Etheostoma kennicotti (Putnam), stripe-tailed darter. 0.2% — Two specimens taken over bedrock.

Etheostoma gracile (Girard), swamp darter. 0.1%—Single specimen. Hubbs and Cannon (1935), in listing specimens they examined for a revision of the genera *Holoepis* and *Villora,* included a specimen taken from Sugar Creek by Stephen A. Forbes on October 16, 1900. *Hololepis gracilis* (Girard) is a synonym used previously for the species currently referred to as *Etheostoma gracile* (Girard).

Hadropterus maculatus (Girard), blackside darter. 0.1% — Single specimen.

Family Centrarchidae

Lepomis cyanellus Rafinesque, green sunfish. 10.4% — Evenly distributed along entire stream.

Lepomis megalotis (Rafinesque), longear sunfish. 4.6% — Rather evenly distributed along entire stream.

Micropterus punctulatus (Rafinesque), spotted bass. 1.7% — Largest spotted bass (9 inches total length) taken in lowermost stations; young-of-the-year and subadults more abundant upstream.

Pomoxis annularis Rafinesque, white crappie. 0.7%—Six young-of-the-year.

Chaenobryttus coronarius (Bartram), warmouth. 0.5% — Four young-of-the-year taken in lower reaches of stream.

Micropterus salmoides (Lacépéde), largemouth bass. 0.4% — Three specimens taken in uppermost stations.

Lepomis macrochirus Rafinesque, bluegill. 0.1%—Single specimen.

Discussion

The redfin shiner, which constituted 35.3% of the total sample, was the most abundant species collected in Sugar Creek. The bluntnose minnow, which constituted 13.2% of the total sample, was second in abundance. Thus, these two species alone accounted for almost one-half of the total sample.

It is of interest to compare the fish population of Sugar Creek with the populations of some other southern Illinois streams. Roaring Springs Creek near Anna, Illinois, contains a population in which the creek chub and the stoneroller are the most abundant species and constitute 39.2% and 22.9%, respectively, of the total sample (unpubl. data). The most abundant species in Clear Creek, near Alto Pass, Illinois, was found to be the stoneroller which constituted 65% of the total population (Lewis and Elder, 1953). The stoneroller and bluntnose minnow are the most abundant species in the Big Creek drainage of Hardin county, Illinois (unpubl. data).

Fishery Values

In order of abundance, the fishes of Sugar Creek that might interest

the angler are: green sunfish, longear sunfish, spotted bass, yellow and black bullheads, white crappie, warmouth, largemouth bass, and bluegill. Scarcity rules out the importance of the latter six species. The spotted bass, longear sunfish, and green sunfish might prove of some importance but cannot offer too much fishing due to their small size in this particular fish population. The stream might best be used as a bait source, since it contains several good bait species, namely the redfin shiner, bluntnose minnow, and creek chub.

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FACTORS INFLUENCING EXCESSIVE FLOWS OF COAL STRIP-MINE EFFLUENTS

JOHN DAVID PARSONS
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Introduction

The production of "sulfur water" (sulfuric acid) by coal and the associated strata led to the discovery of coal in the United States about 250 years ago. Gabriel Thomas wrote in 1698, "I have reason to believe there are good coals also for I have observ'd the runs of water have the same colour as that which proceeds from the coal mines in Wales" (Eavenson, 1942).

Such acid issuing from undisturbed areas as well as from mines was observed more than 150 years ago.

"In 1803 T. M. Morris noted: 'But the spring water, issuing through fissures in the hills, which are only masses of coal, is so impregnated with bituminous and sulphurous particules as to be frequently nauseous to the taste and prejudicial to the health.' And six years later, Joshua Gilpin visited a coal mine and wrote: 'Above the coal is several feet of a mixed kind of bad coal and iron abounding in sulfur and in vitriol effloresing in white and yellow crystals.'" (Braley, 1954a)

Therefore, the production of acid is not due to man's operations but is a normal reaction between the oxygen of the air and the sulfur and iron materials associated with the coal strata. Man's role, then, has been, and still is, one of increasing the amount of exposed material containing iron and sulfur and, consequently, the amount of acid produced.

It was first generally agreed that the oxidation of pyrites (iron sulfide) alone was responsible for the formation of acid mine-water (Winchell, 1907; Patrick, 1933; Trax, 1933). Frost and Streeter (1924) hinted at more than one form of sulfuritic iron when speaking of the acid mine-waste resulting from oxidation of the sulfides of iron. Specific reference to a second form of iron sulfide, marcasites, was made by Carpenter and Herndon (1933), Herndon and Hodge (1936), Hodge (1938), U. S. Public Health (1942), and Hoffert (1947). The excellent work of Braley (1954b) discovered a third form of iron sulfide, black amorphous pyrite. These forms differ not only in crystalline form (Hoffert, 1947; Braley, 1954b), but also in: 1) rate of reaction; 2) resultant pH; and 3) grams of sulfate produced (Braley, 1954b).

The first commercial mining of coal in the United States was begun in 1820. Within 30 years the Western Interior Coal Province of Iowa, Missouri, Arkansas, Kansas, Oklahoma, and Nebraska had been opened by stripping methods. By 1939, 119 years after the first commercial mining of coal in North America, strip-mining methods accounted for only 3.1% of all bituminous coal mined in the United States. The greatest advance in the percentage of bitumi-

nous coal mined by the strip method has occurred in the past 15 years; as a result, the production has increased to over 26% of the total of all bituminous coal mined.

Acknowledgments

The author wishes to express his gratitude to Dr. Robert S. Campbell, Professor of Zoology, University of Missouri, for his guidance and assistance in this investigation. Thanks are also due P. G. Barnickol, Senior Fisheries Biologist, Herbert Fisher, Fisheries Biologist, and Conservation Agent Allen Hoefelman, all of the Missouri Conservation Commission, for their help and encouragement.

This paper is a contribution from the Missouri Cooperative Wildlife Research Unit—U. S. Fish and Wildlife Service, Wildlife Management Institute, Missouri Conservation Commission, Edward K. Love Foundation, and University of Missouri cooperating. The author wishes to express his appreciation for the financial assistance accorded him through a fellowship of the Edward K. Love Foundation.

Description of Area

The study area was on the southern edge of the easternmost projection of the Western Interior Coal Province and located in central Missouri north of the Missouri River in the counties of Boone and Callaway. The extent of this coal province has been described by Campbell (1922).

Intensive research was conducted on Cedar Creek and associated strip-mine areas for a period of 27 months, June, 1952, to August, 1954, inclusive.

Cedar Creek is 44.4 miles long, running in a north-south direction with a total drop in relief of 300 feet, or a drop per mile of approximately 6.7 feet. It has a mean velocity of one-third foot per second with a traversal time of approximately eight days. The stream valley is narrow, and Cedar Creek drains approximately 200 square miles, an average of 5 square miles of watershed for each linear mile of stream.

Because of the upstream location of the source of the pollution on Cedar Creek, only Station 1 could be located above the polluted area. Stations 2 through 7 were in an area of continuous pollution, and Stations 8, 9, 10, 10a, 10b, 11, and 12 were in a downstream area which was periodically polluted (Fig. 1). Station 9 (Fig. 2) was selected as representative of the stream with a narrow valley, rock outcrop, and high bluff typical of the middle and lower watershed.

The general appearance of the strip-mine areas of this study is shown in Figure 3. The physical relationship of the strip areas to Cedar Creek and its tributaries is shown in Figure 1. Only those areas which had a role in the pollution of Cedar Creek are designated.

Pollution Problem

There were two different aspects of acid mine pollution in Cedar Creek. The upstream area, Stations 2 through 7, was continuously polluted by acid mine-effluents originating in the strip-mine areas above Station 5 (Fig. 1). The downstream area, Stations 8 through 12, was considered unpolluted. However, during excessive flows of acid mine-effluents, part, or all, of the

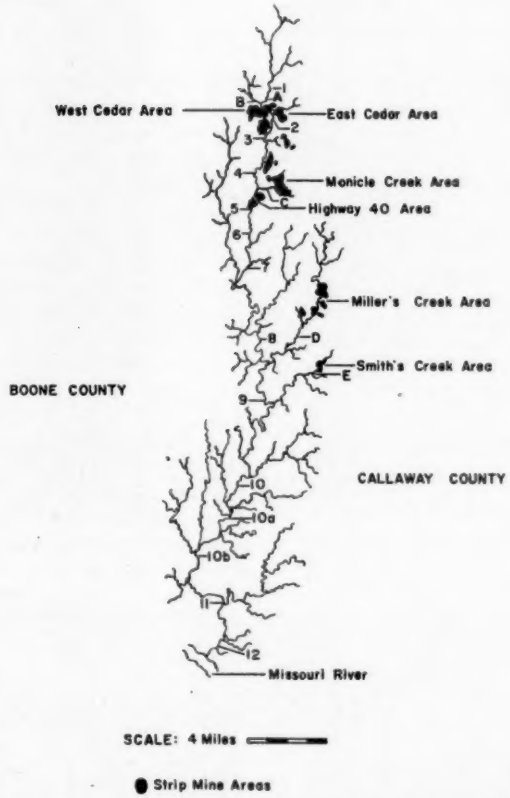

FIG. 1.—Cedar Creek sampling stations and related strip-mine areas.

latter area was polluted.

It is suggested that an excessive flow of acid mine-water into the unpolluted downstream area (Stations 8 through 12) occurs in two phases: 1) the initiation; and 2) the maintenance.

The initiation of an excessive acid flow occurs in the strip-mine area in the Cedar Creek Valley immediately above Station 5. A sizable portion of this area drains, in terms of strip-pile runoff, directly into Cedar Creek. Here, as on the other strip-mine lands of this general area, salts produced by the breakdown of iron sulfide are concentrated by evaporation at the surface of the spill piles. Large amounts of the various sulfate salts accumulate during the warmer months of the year under the high temperatures

and prolonged dry periods. It appears that rainfall initiates excessive acid flows by dissolving the various sulfate salts from the spill piles and carrying the resultant effluent ions into the stream.

The maintenance of an excessive acid flow, to the extent that the downstream unpolluted area is affected, depends primarily upon the addition of effluent ions from the overflow of strip-mine lakes. Thus, the level of the strip-mine lakes is important, for if maintained at a high level the effluent overflow during a rain increases the distance which the acid flow will travel.

Discussion

There were four, excessive acid flows during the study period of June, 1952, through August, 1954. These flows occurred in August, 1952, July, 1953, and May and June, 1954. The above acid flows were under close observation from the time they entered the downstream unpolluted area (Stations 8 through 12) until they were dissipated.

The excessive acid flows of August, 1952, and May, 1954, were alike in that they were partial flows; *i.e.*, they did not pollute the entire, downstream, usually unpolluted area of Cedar Creek. However, the dissipation of these flows was different. The dissipation of the August, 1952, flow was initiated by relatively high water which limited the toxic effects to four days. The flow of May, 1954, remained in Cedar Creek six days and was apparently dissipated by bicarbonate buffer introduced by the tributaries.

The partial acid flow of August, 1952, originated in the strip areas located above Station 5. This flow was apparently initiated and maintained by the spill-pile runoff, which contained the effluent ions of the numerous salt deposits which had accumulated in large masses, for the strip-mine lakes did not contribute to this excessive acid flow. The partial flow of May, 1954, was initiated and maintained in the same manner. Apparently, the initiation of an acid flow originates from spill-pile runoff of accumulated salts, and, without the addition of overflow from the strip-mine lakes, the flow is of insufficient volume to carry through the entire, downstream, unpolluted area.

The excessive acid flows which were considered complete occurred in July, 1953, and June, 1954. Both flows polluted the entire, downstream, unpolluted area but were of different intensities. The excessive acid flow of July, 1953, which affected the entire length of Cedar Creek to the Missouri River, remained toxic at several downstream stations for some months, whereas the flow of June, 1954, was dissipated within 12 hours.

The complete flow of July, 1953, originated in the strip-mine areas located above Station 5 and was maintained by spill-pile runoff plus the overflow of the lakes in these areas. The complete flow of June, 1954, was initiated and maintained entirely by the spill-pile runoff. As in the case of the partial acid flows, the complete acid flows originated from the spill-pile runoff of accumulated salts. The addition of the overflow from the strip-mine lakes increased the initial flow of July, 1953, to such volume that it carried into the unpolluted area. Since

FIG. 2.—Station 9, Cedar Creek; typical of middle and lower watershed.

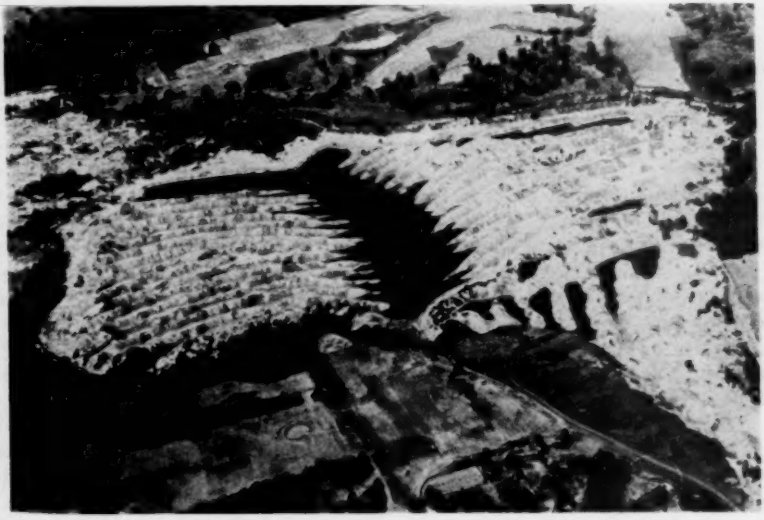

FIG. 3.—Typical strip-mine area and strip-mine lake in upper Cedar Creek area.

the volume of this complete flow was made up entirely of effluent water, the intensity of the flow was great and the effects severe and prolonged. However, without the addition of effluent ions contributed by the overflow of the strip-mine lakes but with continuing rainfall, the excessive flow of June, 1954, though being rapidly dissipated, was of sufficient volume to carry through the unpolluted downstream area.

The rate of recovery of the downstream area varied widely during the study period. The acid flow of August, 1952, moved into the unpolluted area on August 17 but was rather quickly dissipated by relatively high water on August 21. Thus, though the flow was of such intensity as to cause a fish kill at Stations 8 and 9, the recovery of these stations was quite rapid.

The flow of July, 1953, was not only intense but also of long duration. This relatively large flow entered the unpolluted area on July 5. By late afternoon of the following day the flow was below Station 11, and the effluents were affecting the smaller fishes. By the second day of the flow the silt load had precipitated in the downstream, unpolluted area, resulting in the accumulation of a light-brown floc on the bottom of the stream. Even at the end of a six-day period only a slight recovery was noted at Station 11; however, by this time the flow had slowly proceeded to within one-fourth-mile of the Missouri River. Within ten days, Stations 9, 10, and 11 showed marked recovery, yet Station 12 was still quite acid. Toxic, acid mine-water continued to flow into Station 8, whereas the initial flow remained toxic at Station 12. This was probably due to the following facts: 1) no rain had followed the initial acid flow and thus there was no excessive non-acid water flow from either the tributaries or upper Cedar Creek; 2) by the nature of an acid flow, the intensity decreases progressively downstream and, therefore, the acid flow was less concentrated at Station 12; and 3) the comparatively low gradient from Station 12 to the Missouri River retarded the rate of flow, and the acid flow acted as a "plug" in the lower reaches of Cedar Creek. This plug remained in Cedar Creek for at least 15 days. Meanwhile, upstream from Station 11 the stream was recovering. However, farther upstream the flow of acid water into Cedar Creek was such as to contribute to the continued pollution of Station 8 which did not recover until the time of the October rains with the subsequent increase in the volume of unpolluted water from the tributaries.

On May 7, 1954, an acid flow reached Station 10a (Fig. 1), but it was apparently weak for Stations 10 and 10a showed recovery the next day, and no dead fishes were found at either station. Within six days there was a progressive decrease in the concentrations of effluent ions at Stations 9, 10, and 10a. However, at Station 8 these concentrations remained high because of a small, continuous, excessive acid flow.

The recovery of the unpolluted downstream area, following the excessive acid flow of June, 1954, was quite rapid, for this flow was dissipated by unpolluted water which followed the acid flow, diluting it upstream as the unpolluted downstream water blunted the forward movement. Thus, by the time the

acid flow had reached Station 11, it had dissipated to such an extent that it was only 300 yards in length.

In the final analysis, not only the initiation of a flow, the maintenance of such a flow, the concentrations of effluent ions, and the distances of excessive acid flow travel, but also the rate of recovery of the downstream area were dependent upon a delicate, everchanging balance in the amount, distribution, and intensity of rainfall, and, to some extent, upon the time interval between rains.

Two approaches to the control of the pollution of Cedar Creek have been offered: 1) the addition of various chemicals to render the effluent ions harmless to aquatic life; and 2) the physical movement of earth as: a) building dams; b) draining strip-mine lakes; and c) diverting runoff from surrounding areas.

The destruction of effluent ions by chemical reaction has been proven economically unfeasible in a number of studies (Carpenter and Herndon, 1933; Trax, 1933; Hodge, 1938; Penn. State Bd. Health, 1951). However, the physical movement of earth appears to have merit in partially eliminating excessive acid flows.

The construction of diversion dams to control the runoff entering the Cedar Creek strip-mine areas from the surrounding unstripped land would be impractical, for the strip areas are of such size that a flow could be initiated by the water which falls in the area itself. However, by the construction of such dams, it might be possible to control the overflow from lakes which receive a sizable runoff from the unstripped land.

The drainage of strip-mine lakes also has been offered as a possible solution. However, the drainage of two lakes of the study area showed this method to be inadequate. Large amounts of sulfate salts were found to accumulate on the spillpiles adjacent to the drained pits, and rainfall continued to carry the resultant effluent ions directly into Cedar Creek.

On the basis of the information gathered during this study of the Cedar Creek area, the following suggestions are made. There is enough strip-mine area on which sufficient salt accumulation may occur to pollute continuously the upstream area (Stations 2 through 7). It would not be economically feasible to correct this situation by any combination of proposed methods.

Since it has been illustrated that the lakes do not contribute to the chemical breakdown of iron sulfide (Parsons, 1955), it appears that the lakes would be ideal holding areas for effluent ions. It also has been shown that the lakes must contribute to an excessive acid flow for the flow to be of such volume and intensity as to cause a severe fish kill; thus, the acid mine-water of these lakes must be contained. The key to the problem appears to lie in maintaining a relationship between watershed and lake volume such that the normal rainfall-evaporation ratio will limit the volume of water accumulated and prevent the overflow of acid water.

It is proposed that the overflow from the strip-mine lakes of the Cedar Creek area may be controlled by: 1) restriction of water to the strip pit by the construction of dams in low areas adjacent to the strip pit; and 2) restriction of excessive runoff from adjacent unstripped

lands into the pits by the construction of diversion dams.

Summary

1. The production of acid mine-water is not due to man's activities but is a natural, oxidative, chemical process.

2. The potential amount of acid mine-water depends upon both the type and the amount of sulfuritic material exposed.

3. The increase in both the incidence and the intensity of coal strip-mine pollution is due to an increase of more than 26% in strip-mining activities.

4. There are two different aspects of acid mine pollution in Cedar Creek. The upstream area is continuously polluted, whereas the downstream area is periodically polluted by excessive acid flows.

5. There are two major sources within the strip-mine areas which contribute to both the continuous and the periodic pollution of the stream: 1) the accumulated sulfuritic salts on the spill piles; and 2) the strip-mine lakes.

6. Contributions from both sources are necessary to produce an excessive acid flow of such intensity as to be detrimental to the fauna of the unpolluted area of the stream.

7. The initiation, maintenance, extent, and intensity of an excessive acid flow and the rate of recovery of the stream are a function of the amount, intensity, and distribution of rainfall and, to some extent, of the time interval between rains.

8. Because of the proximity of strip piles to Cedar Creek, it is neither practical nor economically feasible to correct the continuous pollution of the upstream area.

9. Control of excessive acid flows depends upon the maintenance of a relationship between watershed and lake volume such that the normal rainfall-evaporation ratio will limit the volume of accumulated water, thus preventing acid-water overflow.

10. It is plausible that control of strip-lake overflow may be attained by the construction and maintenance of earthen dams in the strategic areas adjacent to strip-mine lakes.

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BOAT FISHERMEN'S CATCH AT CRAB ORCHARD LAKE, LAKE MURPHYSBORO AND HORSESHOE LAKE, DURING 1955

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To obtain some dependable measure of fishing success in southern Illinois, creel censuses were carried out on three southern Illinois lakes. The study was a cooperative one between the Illinois Department of Conservation and the Cooperative Fisheries Research Laboratory and the Department of Zoology of Southern Illinois University. The U. S. Fish and Wildlife Service granted permission to conduct the Crab Orchard Lake census. The census at Crab Orchard Lake, a 6,600-acre reservoir, was started March 12 and ended October 1. It was made on 28 days evenly distributed throughout this period. On the basis of an estimate obtained by aerial count of fishing boats in connection with a creel census in 1954 (Newton and Lewis, 1956), the present census represented a check of 41% of each day's boat fishing.

A total of 954 man-hours of fishing with minnows was recorded. The resulting catch represents a rate of 0.38 crappie, *Pomoxis* spp., per man-hour which is considerably below the rate of 0.52 per man-hour recorded for the 1954 season (Newton and Lewis, 1956). This catch-rate is also low in comparison to catch-rates reported in Carlander (1950).

Plug fishing showed some improvement over the 1954 season. The 1955 catch in 999 man-hours of fishing resulted in a catch of 0.09 largemouth bass, *Micropterus salmoides,* per man-hour. The 1954 rate was 0.5. But even though there was some improvement in 1955, the rate was still very poor in comparison to Carlander's listing.

A total of 106 man-hours of worm-fishing was recorded. There were 14 small bluegill, *Lepomis macrochirus;* 14 carp, *Cyprinus carpio;* 2 freshwater sheepshead, *Aplodinotus grunniens;* and one yellow bullhead, *Ameriurus natalis.* This amount of fishing hardly constitutes enough of a sample to justify any conclusions as to rate of catch. The limited amount of worm-fishing is, however, indicative of the poor reputation the lake has acquired in the production of fishing for bluegill and bullheads.

Only one fly fisherman was encountered. He had no success in three hours of fishing. Spinning and casting equipment have become so similar as to often make classifying impossible, hence the two are both classed as plug fishing.

Inasmuch as a census was carried on at Crab Orchard Lake during 1954, a comparison of fishing intensi-

ty in the years 1954 and 1955 is possible. Since the 1955 census was limited to Saturdays, for purposes of comparing fishing pressure, only the Saturday censuses of 1954 were considered. The 1954 data included 29 Saturdays of creel census whereas the 1955 data included 27 Saturdays. The average man-hours of fishing per day by different methods was as follows for 1954: fishing with minnows, 163, and with plugs, 72. The similar values for 1955 were: fishing with minnows, 35, and with plugs, 37. It is evident that the fishing pressure at Crab Orchard had greatly decreased.

Lake Murphysboro is a 173-acre, artificial impoundment located in Jackson County, Illinois. It filled in 1950. It has a maximum depth of 35 feet and is quite accessible for fishing. When partly full it was poisoned with rotenone to eliminate the wild fish population. It was then stocked with adult largemouth bass and with bluegill, redear sunfish, *Lepomis microlophus,* and channel catfish, *Ictaluris punctatus.* The present fish population includes: the above species; white crappie, *Pomoxis annularis;* green sunfish, *Lepomis cynellus;* warmouth, *Chaenobryttus coronarius;* European carp; and a few miscellaneous forms.

The Lake Murphysboro census was taken at the lake's only boat dock every Wednesday through Sunday from 7 a.m. to 7 p.m. from June 15 until July 1, and every Wednesday, Thursday, and Sunday from July 1 until September 15, 1955.

At Lake Murphysboro fishing with worms and cockroaches was the most popular type of fishing and produced a per-man-hour rate of catch of 1.29 bluegills and 0.26 redear sunfish plus a combined catch of largemouth bass, crappie, and channel catfish amounting to 0.05 fish. Worm fishing at Lake Murphysboro was by far the best fishing recorded.

A total of 237 man-hours of plug fishing at Lake Murphysboro produced 0.07 bass per man-hour.

Only 198 man-hours of fishing with minnows were recorded at Lake Murphysboro. This fishing produced a catch of 0.13 bass and 0.10 crappie per man-hour. For crappie this was fairly good but for bass it was poor.

Sixty-seven man-hours of fly fishing at Murphysboro Lake resulted in a catch of bluegill, redear, and largemouth bass of 0.15, 0.02, and 0.25 fishes per man-hour.

The principal fishing at Horseshoe Lake was minnow fishing. Minnow fishing produced 0.36 crappie per man-hour and practically no bass or other fishes, a poor rate. There was very little plug fishing at Horseshoe Lake and the catch in the 78 man-hours recorded was poor. One hundred and forty-one man-hours of fishing with worms and cockroaches at Horseshoe produced 0.94 bluegill per man-hour and 0.08 crappie per man-hour. This was a good rate for bluegill, but poor for crappie.

Of the three lakes and the various types of fishing, probably the only satisfactory result was the sunfish catch of Murphysboro Lake and these fishes were fairly small.

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BOTANY

EFFECT OF SUBSTRATE HYDROGEN PEROXIDE ON GROWTH OF BORON DEFICIENT PLANTS

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Boron nutrition of plants has been extensively investigated and numerous functions for this element have been suggested (Gauch and Dugger, 1954). Shkolnik *et al.* (1951, 1952, 1954) have indicated one function as that of bringing about increased oxygen supply to the tissues, particularly to those of the roots. Experimenting with flax grown in the absence of boron (Shkolnik and Steklova, 1951, 1954), they noted that the addition of hydrogen peroxide to the nutrient solution resulted in the development of normal appearing plants. Inasmuch as an oxygen supplying agent seemed to replace boron effectively, they postulated that this element was somehow concerned with provision of an adequate oxygen supply to the tissues.

The present investigation was undertaken to determine whether substrate applications of hydrogen peroxide could alleviate boron deficiency in tomato, *Lycopersicon esculentum;* cotton, *Gossypium hirsutum;* and turnip, *Brassica Rapa.*

Material and Methods

Bonny Best tomato, Stoneville 2B cotton, and Purple Top White Globe turnip were the varieties utilized in this study. The plants were grown in the greenhouses at the University of Chicago during the period of April 12 to June 14, 1954. The first few weeks of this period were marked by relatively cool temperatures and overcast skies. During the final weeks, sunny and very warm days prevailed. Seeds were sown in quartz sand in quart, glazed jars. When the first true leaves of the seedlings began to expand, the plants were thinned to a uniform stand of two per jar.

With each species, three treatments were instituted, namely: adequate boron (B), inadequate boron (B—), and inadequate boron plus hydrogen peroxide (B—H_2O_2). Eight jars were included in each treatment, and the jars were randomly distributed within each plant group. Hoagland and Arnon's (1950) macronutrient solution 1 was utilized for all series. The micronutrient elements—manganese, zinc, copper, and molybdenum—were added to this solution in concentrations of 0.5, 0.05, 0.02, and 0.01 p.p.m., respectively. The solution of the B series received, in addition, 5 p.p.m. of boron. Uniform amounts of nutrient solution were applied 3 times per week, and distilled water containing 5 p.p.m. iron tartrate was added on other days. In the B—H_2O_2 series, daily applications

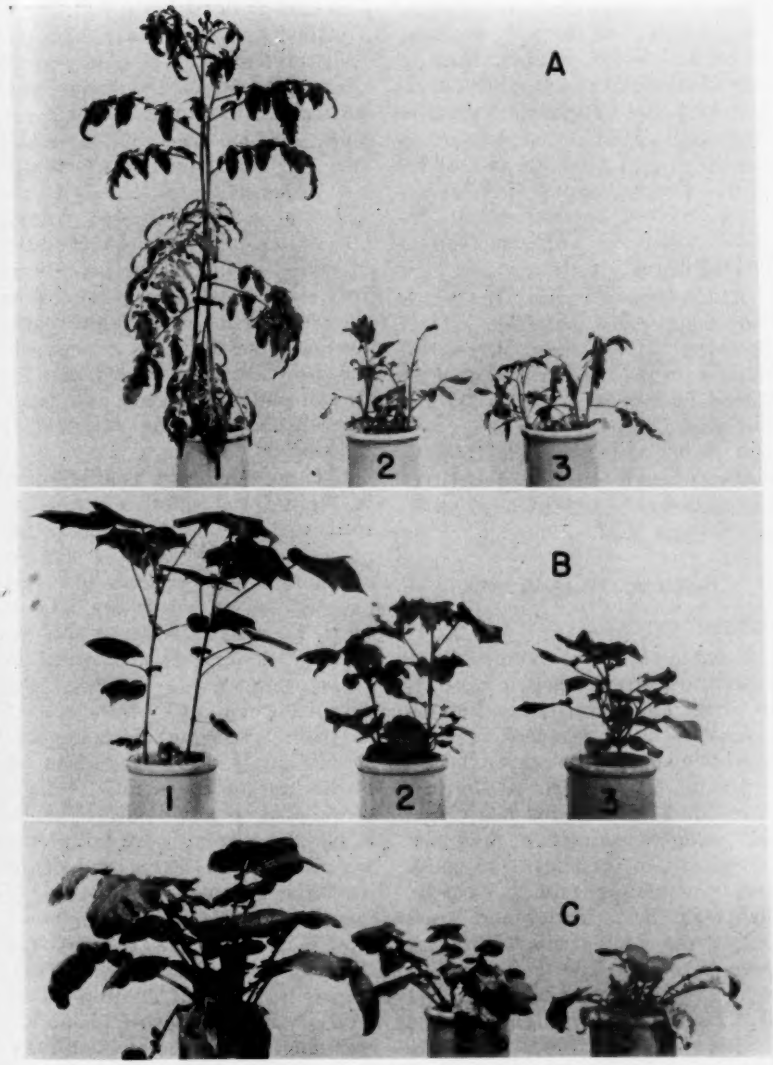

FIG. 1.—Tomato (*A*), cotton (*B*) and turnip (*C*), plants grown under conditions of adequate boron (1); inadequate boron plus hydrogen peroxide (2); and inadequate boron (3).

of hydrogen peroxide at a concentration of approximately 5 p.p.m. were made. The peroxide was combined with boron-deficient, nutrient solution or distilled water immediately prior to use. The various nutrient treatments were initiated approximately a week after the seeds were sown. Previous to this time all cultures received applications of distilled water or nutrient solution lacking boron.

At the time of harvest, the plants were fractionated and fresh weights obtained. Dry-weight determinations were made after drying in a forced-draft oven at 80°C. The dry material was ground in a Wiley mill (80 mesh), ashed at 450°C. in a muffle furnace, and analyzed for boron content by the curcumin method of Dible *et al.* (1954).

Results and Discussion

Growth responses

Tomato.—Lack of boron in the nutrient substrate resulted in necrosis of the apical meristem with consequent reduction in stem height and number of main stem leaves and increase in the number of laterals (Fig. 1). The boron deficient plants also produced malformed, thickened leaves, which exhibited brownish purple discoloration. Visually, plants of both inadequate boron series were very similar, although those in the B—H_2O_2 group tended to be slightly shorter in height and have fewer leaves and laterals. The smaller size of the B—H_2O_2 plants, as compared to the B— group, was reflected in lower tissue fresh and dry weights (Table 1). The fresh and dry weights of the tissues of plants grown under conditions of inadequate boron were significantly less than those of the B series.

Although the percentage dry weights of the roots of plants on the inadequate boron treatments were higher than those on adequate boron, such was not true for leaves and stems. It is interesting to note that the boron concentration of the tissues followed a similar pattern (Table 2). The top-to-root ratios of plants on inadequate boron were very similar and slightly lower than that for the B series. Thus, under the conditions of this experiment, the growth data indicated that hydrogen peroxide did not adequately replace boron in the nutrition of tomato.

Cotton.—Similarly, lack of boron in the nutrient solution applied to cotton plants resulted in a reduction in main-stem growth and number of main-stem leaves and increased development of vegetative laterals (Fig. 1). Leaf malformations—including thickening, distortion in shape, repression of lobing, and downward cupping — were evident on plants receiving an inadequate boron supply. A comparison of plants in the B— and B—H_2O_2 series, however, revealed that plants in the latter group were taller, had more main-stem leaves and fewer vegetative laterals than those in the former (Fig. 1). This improved growth in the B—H_2O_2 series was also reflected in higher fresh and dry weights (Table 1). The top-to-root ratio of peroxide-treated plants exceeded that of boron-inadequate untreated and even more that of boron-adequate plants. Although some improvement in growth was noted with hydrogen peroxide applications, plants in this group were

TABLE 1.—Effect of Nutrient Treatment on Fresh and Dry Weight, Percentage Dry Weight, and Top-to-root Ratio of Tomato, Cotton and Turnip Plants.

Series	Roots			Leaves			Stems			Top to root ratio[2]
	Fresh[1] wt.	Dry[1] wt.	% dry wt.	Fresh wt.	Dry wt.	% dry wt.	Fresh wt.	Dry wt.	% dry wt.	
TOMATO										
Adequate boron	9.49	0.94	9.91	23.35	3.39	14.52	22.26	2.85	12.80	6.6
Inadequate boron	1.81	0.24	13.26	6.52	0.81	12.42	3.83	0.49	12.79	5.4
Inadequate boron plus H_2O_2	1.40	0.18	12.86	4.83	0.55	11.39	2.86	0.35	12.24	5.0
COTTON										
Adequate boron	10.29	1.37	13.31	13.61	2.67	19.62	5.08	1.55	30.51	3.0
Inadequate boron	1.61	0.26	16.15	3.38	0.65	19.23	1.30	0.39	30.00	4.0
Inadequate boron plus H_2O_2	1.74	0.47	15.85	4.40	0.86	19.55	1.77	0.53	29.94	4.9

Series	Roots			Shoots			Top to root ratio[2]
	Fresh wt.[1]	Dry wt.[1]	% dry wt.	Fresh wt.	Dry wt.	% dry wt.	
TURNIP							
Adequate boron	26.92	3.01	11.18	42.48	4.63	10.90	1.5
Inadequate boron	1.89	0.36	19.05	10.63	1.74	16.37	4.8
Inadequate boron plus H_2O_2	2.48	0.29	11.69	9.97	1.46	14.64	5.0

[1] Fresh and dry weights in grams.
[2] Based on dry weights.

still significantly smaller than those supplied with adequate boron, indicating that peroxide did not effectively replace boron.

Turnip.—Boron deficiency in turnip was manifested by a stunting of the plants, a decrease in size and number of leaves, and a tendency for the leaves to curl and become highly tinted with yellow, orange, red, and purple areas (Fig. 1). The fleshy roots failed to grow and, at the time of harvest, measured only one-third the diameter of those from plants on adequate boron. The roots of deficient plants also exhibited necrotic lesions. The addition of hydrogen peroxide to the substrate did not appear to alleviate these symptoms in any way. The fresh and dry weights of the roots and shoots of plants on deficient boron were significantly less than those on an adequate supply (Table 1). The top-to-root ratios were much higher in boron deficient plants. This apparently indicated a greater influence of boron deficiency on root growth of turnip than on the other species studied.

TABLE 2.—Effect of Nutrient Treatment on Distribution of Boron in Tissues of Tomato, Cotton and Turnip Plants.

Series	Roots		Leaves		Stems		Total
	mg.:kilo	μg.:plant	mg.:kilo	μg.:plant	mg.:kilo	μg.:plant	μg.:plant
TOMATO							
Adequate boron	51.7	48.6	347.4	1177.7	18.0	51.4	1277.7
Inadequate boron	54.5	13.1	12.7	10.3	11.9	5.8	29.2
Inadequate boron plus H_2O_2	66.2	11.9	15.7	8.7	12.0	4.2	24.8
COTTON							
Adequate boron	57.6	78.8	120.8	322.6	12.4	19.3	420.7
Inadequate boron	76.7	19.9	27.2	17.7	7.4	2.9	40.5
Inadequate boron plus H_2O_2	71.8	20.1	24.2	20.8	6.2	3.3	44.2

TURNIP

Series	Roots		Shoots		Total
	mg.:kilo	μg.:plant	mg.:kilo	μg.:plant	μg.:plant
Adequate boron	54.2	163.1	344.3	1594.3	1757.4
Inadequate boron	21.1	7.6	20.3	35.2	42.8
Inadequate boron plus H_2O_2	33.4	9.7	22.4	32.7	42.4

CHEMICAL ANALYSES

Analyses of the tissues of plants for relative distribution of boron revealed a difference in plants grown under conditions of inadequate supply and those receiving an adequate amount. Plants receiving sufficient boron had the highest concentration, as well as the greatest total amount in the leaves or shoots (Table 2). With an inadequate supply, however, the greatest concentration was always observed to be in the roots. In the B— series the largest total quantity was found in the roots of tomato and cotton, while in turnip the largest quantity was in the shoots. The roots of tomato contained the greatest total amount in the B—H_2O_2 group, whereas in coton the quantities in the roots and leaves were comparable. With turnip of the B—H_2O_2 series, more boron was observed in the shoots. Although, on the basis of concentration, boron in the roots of tomato and cotton plants exhibiting deficiency symptoms exceeded that found in those not showing such signs, such was not true for turnip.

Tomato and turnip plants on an adequate boron supply accumulated over three times as much of this element as did cotton (Table 2). In the deficient series, however, cotton and turnip contained more boron than tomato. In all instances the total boron content of whole plants or tissues was significantly higher in the B group.

In a comparison of the B— and B—H_2O_2 series, the only instance of a significant difference in concentration or total quantity of boron was in the roots of turnip. It is of interest to note in this instance that, although the B—H_2O_2 roots contained more boron than those of the B— series, neither the total quantity in the plant nor the amount of dry matter produced was greater. It is obvious, therefore, that the addition of hydrogen peroxide to the substrate did not result in a substantial change in the pattern of boron distribution or in the total boron content of the plants.

ACKNOWLEDGMENTS

This work was supported in part by a grant from the Dr. Wallace C. and Clara A. Abbott Memorial Fund of the University of Chicago.

SUMMARY

To determine if hydrogen peroxide could replace the requirement for boron in tomato, cotton, and turnip, plants were grown in sand culture under three regimes of boron nutrition, namely: adequate boron, inadequate boron, and inadequate boron plus hydrogen peroxide. Hydrogen peroxide was added to the substrate daily, either in nutrient solution or distilled water in a concentration of approximately 5 p.p.m.

Growth measurements indicated plants of the inadequate boron plus hydrogen peroxide series were more comparable to the inadequate-boron group than to those of the adequate-boron treatment. Only with cotton was any improvement in growth noted as a result of hydrogen peroxide treatment. Deficient plants normally exhibited the greatest concentration of boron in the roots, whereas in plants with adequate boron the concentration was highest in the leaves. The addition of hydrogen

peroxide to the substrate did not result in a substantial change in the pattern of boron distribution or in the total boron content of the plants.

Under the conditions of this experiment, the results obtained did not support the hypothesis that boron is effectively replaced by hydrogen peroxide in tomato, cotton, or turnip.

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Illinois Academy of Science Transactions, Vol. 49, 1956

A METHOD FOR OBTAINING MITOTIC FIGURES IN SEEDLINGS OF *ALISMA* [DILL.] L.

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Introduction

Root-tips have been most widely used as a source of mitotic figures because they are ordinarily quite accessible. For example, in classroom study of mitosis, *Allium* root-tips, grown from bulbs, are easy to prepare. However, the number of root-tips that can be obtained from seedlings is often limited. This is especially true in many aquatic plants which are difficult to grow in the laboratory. Other meristematic tissue may be used for taxonomic work because it is only necessary to have a few cells in phases that show the chromosomes distinctly.

While making rapid-smear preparations of root-tips from seedlings of *Alisma* (water-plantain) for another project, the author found few mitotic figures in root-tips. This dearth of proper mitotic figures led to the conjecture that perhaps meristematic tissue other than root-tips in seedlings from monocotyledonous paludal plants might be used. Because shoots and adventitious roots emanate from the epicotyl-hypocotyl axis, various regions of the axis were checked. The presence of good mitotic figures indicated that more detailed examinations of these regions might be profitable, to determine if portions of the epicotyl-hypocotyl axis of *Alisma* plants showed mitotic figures suitable for taxonomic study.

Information from the literature (Maheshwari, 1950; Priestley, 1928; Foster, 1936) indicated that the entire epicotyl-hypocotyl axis of the newly-emerged seedling in some monocotyledons might show excellent figures. Despite this fact, entire seedlings have not been used extensively by systematists as a source of mitotic figures.

Maheshwari (1950) described in some detail the embryogeny of *Alisma* and *Saggittaria*. He included a series of drawings by Hanstein (1870) showing the ontogeny of the embryo in *Alisma*. Hanstein's drawings indicated that the shoot apex (plumule) and true leaf-primordium (bud) develop laterally from the embryo axis, with the leaf-primordium forming a collar of meristematic tissues around the shoot's apex. This collar then functions as an intercalary meristem building up the leaf from below. This fact indicates that the apical leaf meristem is not as active as the basal portion of the leaf.

Materials and Methods

Species used in this work were: *Alisma plantago-aquatica* L. var. *michaletii* (Aschers and Graebner) Buchenau; *A. plantago-aquatica* L. var. *parviflorum* (Pursh) Torr.; *A. canaliculatum* A. Br. and Bouche; and *A. gramineum* Gmelin var. *graminifolia* (Wahlenberg) Hendricks. Seeds were collected in various localities in consecutive years and were

germinated by a modification of a technique for cracking seedcoats, devised by Crocker and Davis (1914). The cracked seeds were placed in a petri dish containing approximately 25 ml. of tap water to which 3 drops of 0.25% sodium hydroxide had been added to soften the seed coats. Approximately 50% of the water was replaced with fresh water every other day. The seedlings were kept under artificial light from 7 a.m. to 9 p.m. daily. Their growth patterns were closely followed. Killings were made in Carnoy's solution at various times of day.

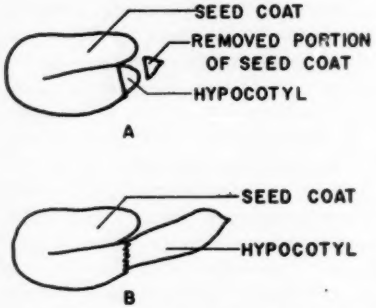

FIG. 1.—*A*, *Alisma* seed with terminal portion of seed coat newly removed; *B*. seed from *A* showing increase in length of hypocotyl occurring in less than 12 hours.

Seedlings were macerated by using a modification of Stewart's method (1950). The tissue was left in the macerating fluid for ten minutes. Some of the seedlings were left in Carnoy's solution as long as seven days, and most of these were not put in macerating fluid. The material was put in proprionic carmine stain for three to five minutes or until the chromatin material stained. Differentiated tissue absorbed very little stain even after immersion in the stain for about 20 minutes. Slides of tissues were made permanent by removing cover slips with 45% acetic acid, dehydrating in alcohol, and mounting in euparol. It was found that the specimen remained on the slide or cover slip better if the stain had started to dry out beneath the cover slip but had not dried as far as the edge of the material. In some seedlings smears were made from only leaf-tips and root-tips; in others, smears were also obtained from leaf-bases, shoot-apices, and the hypocotyl region immediately below shoot-apices.

RESULTS

Growth patterns of seedlings emerging from the seed were as follows: normally, hypocotyls extended from the seed coats first because of their increase in length (Fig. 1). This occurred in practically all of the seeds and did not necessarily indicate that actual growth would follow. In fact, a few showed no further change. Subsequent to this rapid increase in size, the viable seeds appeared to enter a somewhat dormant period for one or two days and, in seeds in one collection, this period lasted about three weeks. The single cotyledon was the last to escape from the seed coat, and it became green in a short time. Next, root-hairs appeared around a collar at the end of the hypocotyl. Between the third and seventh days after the seed coats were cracked, leaves and adventitious roots began to develop in all seeds except those in the collection mentioned above. In the one exception, the seedlings did not foliate for about three weeks. Development in the epicotyl region

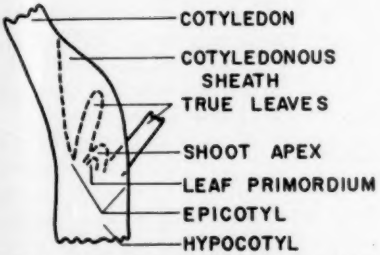

FIG. 2.—Section of young *Alisma* seedling showing epicotyl region with lateral emergence of true leaves from base of shoot-apex.

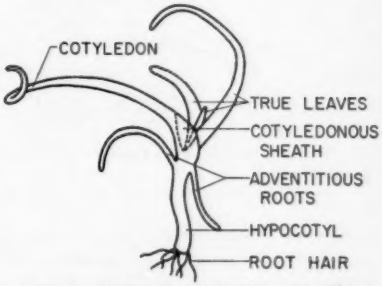

FIG. 3.—Seven-day-old *Alisma* seedling.

occurred before adventitious roots appeared (Fig. 2). True leaves developed from the base of the apical shoot which was covered by a sheath formed by the cotyledon and, shortly, the slender leaves became green. After leaves started to appear, adventitious roots emerged from around the hypocotyl a short distance from the epicotyl (Fig. 3). Sometimes a root would grow out from the end of the hypocotyl.

Seedlings which were in Carnoy's solution from a half-hour to two days and then placed in macerating solution for ten minutes broke down into separated, but complete cells. Plasmolysis of the cells indicated excessive maceration, when seedlings were left in Carnoy's solution longer than two days and then placed in macerating fluid for ten minutes. When seedlings in Carnoy's for six or seven days were transferred directly to 80% alcohol, the cells would separate but were not damaged.

Well-stained meristematic tissue was found in root-tips, leaf-tips, leaf-bases, and leaf-buds, and in the area between the shoot-apices and adventitious roots. In that part of the study in which smears were made solely of root-tips and leaf-tips, mitotic figures were found in only 25% of the seedlings. Figures found in root-tips were usually good; however, when all meristematic portions of the seedlings were examined, mitotic figures were found in 80%. These results were obtained from killings at various hours. Smears made for leaf-primordia, root-tips, and shoot-apices contained more mitotic figures than other areas.

Discussion and Summary

It is known that plants vary in their growth and developmental patterns due to inherited and environmental differences. Patterns of growth in *Alisma* seedlings, with rather slow development of roots and early development of leaves, indicated that the epicotyl and immediately adjacent hypocotyl might provide mitotic figures for systematic work. This was found to be the case; good mitotic figures were found with relative ease in these regions. Inasmuch as there were only two or three roots per seedling, it was more expedient to use other meristematic tissues along with root-tips.

The epicotyl region seemed to be especially meristematic in these aquatic seedlings. Somewhat slow development of the root system, as

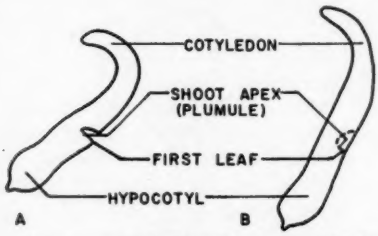

FIG. 4.—*A*, Hanstein's sketch of *Alisma* seedling, adapted from Maheshwari (1950); *B*, *Alisma* seedling, approximately same stage of development as *A*, illustrating cotyledonous sheath.

compared to the foliage, might possibly be the normal growth-pattern of seedlings of other aquatic taxa. *Alisma* seedlings often float for some time before reaching shore.

In searching the literature it was found that root-tips, shoot-apices, and leaf-bases in monocotyledonous plants could be expected to possess meristematic tissue. These views have been verified in *Alisma*.

As a side issue, it is interesting to note that tissue which has been in Carnoy's solution for six to ten days without the usual maceration has good cell separation. Evidently, in about a week the hydrochloric acid in Carnoy's solution macerates sufficiently the small amount of tissue present in plants of *Alisma*. Workers who kill material one week and make smears the following week may find it useful to eliminate one step in the macerating process.

The sheath of the cotyledon that surrounds the shoot-apex seems to be somewhat different from what might be inferred from Hanstein's (1868) diagrammatic sketch of an *Alisma* seedling in Maheshwari's book (1950). His sketch does not show any evidence of the shoot-apex being enclosed by the cotyledon (Fig. 4). The author's findings seem to be similar to Holm's (1890-1891). Holm mentioned "an incipient swelling at the place where the plumule [shoot-apex] has to penetrate".

The initial rapid increase in length of the hypocotyl of newly-exposed embryos did not necessarily mean that all those embryos were viable. In fact, a few of these grew no more and were evidently dead. It may be possible that increase in length of the hypocotyl was due to imbibition.

ACKNOWLEDGMENT

The author wishes to express his appreciation to Dr. Albert J. Hendricks and to the Botany Department, Southern Illinois University, which made this paper possible.

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THE GRAVEL-HILL PRAIRIES OF ROCK RIVER VALLEY IN ILLINOIS

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The prairies of the Midwest have been written about for more than a century. Hill prairies, especially loess and sand prairies such as cover the slopes and tops of the bluffs along the Mississippi River and its tributaries, have been discussed by Vestal (1918), Steyermark (1940), Shimek (1949) and Hopkins (1951). Recently, Evers (1955) has written an excellent article giving in greater detail the occurrence and relative frequency of characteristic species on various Illinois prairies. We are not aware that much has been said about glacial, gravel-hill prairies such as occur in Winnebago County.

Geological and Physical Features

Paralleling Rock River on the east at roughly the edge of glacial Rock River Valley, as shown by the dolomite spurs (Fig. 1), is an interrupted row of gravel hills extending from the Wisconsin line to the mouth of the Kishwaukee River at the south border of Winnebago County. The crest of the hills is at the 800- to 850-foot level. The Rock River is at the 700-foot level. The river has a relatively narrow bottomland, most of the valley being occupied by a gravel terrace which is 50 feet above the river. The bluffs of the terrace are near to or far from the hills, depending upon the bends of the river which determine the width of the terrace. This width varies from a few hundred feet to four miles. It is with the crests of the hills and of the terrace bluffs (Fig. 1) that we are particularly concerned.

The gravel outwash of the various glaciers has filled the old river bed to a depth of more than 250 feet and furnished the water-lain material which forms the terrace and its bluffs. The finer material was carried farther, and thus the terrace soil in the Camp Grant and New Milford area is a sandy rather than a gravelly loam. There is but little till on the terrace, and in many places it is entirely lacking. The hills are of till of pre-Wisconsin age on dolomite bedrock. The sheet of till that forms the hills is of considerable, though of markedly varying, thickness. There is no loess on the terrace and little or none on the hills.

Climate

The climate of Winnebago County, the area under consideration, is continental, not influenced by the Gulf of Mexico and but little by the Great Lakes. The temperature range is to 136° F. (75° C.) from a low of −26° F. (−32° C.). Spring starts late and the season advances rapidly. The last frost is about May 5

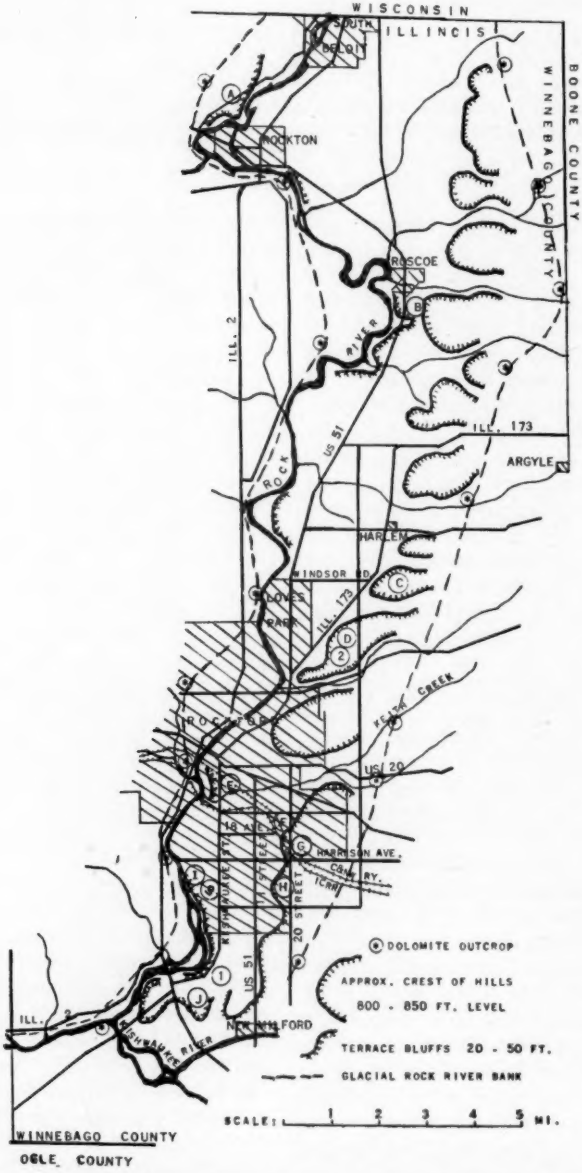

FIG. 1.—Rock River Valley in Illinois: *A* to *J*, prairie patches; *1*, Camp Grant; *2*, Forest Hills Country Club; *3*, Sanitary District plant.

and the first can be expected about September 14. The average precipitation is 34 inches per year of which one-tenth is in the form of about 35 inches of snow. Winds are from the west, more north in winter and more south and strong, frequent and dry in summer.

Vegetation

On Vestal's (1931) vegetational map of Illinois the hills are parallel to the edge of the forest that marks the east border of the Freeport District of the Western Division. The Rock River terrace and the hills, as well as most of the rest of Winnebago County, are prairie. For the most part the floodplain and terrace are treeless, as are also the hills from the Wisconsin line to the junction of Illinois highway 173 with U.S. 51 at the north edge of Rockford. From this point south to the Kishwaukee River the hills and bluffs that are close to Rock River are covered with mixed oaks and hickory. The terrace vegetation, except that of the crest of the bluffs is such as is usually found on sandy prairies, the sand plants being more noticeable in the Camp Grant area. The hills to the east, back of the crests, have a high-prairie vegetation. Near the Boone County line is a transition belt with an oak-opening vegetation indicating the trend to forest, which is apparent in all of northern Illinois. Eastern mesophytes and prairie species mix to form the flora of this belt and of the wooded hills. Southern plants, except for some of the panicums, are not numerous.

On the west side of the river there is only one place, opposite Rockton (area A, Fig. 1), where this formation of terrace bluff and hill is evident. At this point a large ox-bow bend produces a river bluff that faces southwest much as is normally the case on the east bank. The other prairies west of the river are of the low or of the high, flat or rolling type except for a few small "limestone prairies" where the dolomite is very near the surface.

The plants of the crests of the hills and bluffs differ materially from those of such places as high or low, flat prairies, the Mississippi "goat prairies" in Pike County, the St. Peter sandstone hills around Castle Rock in Ogle County, the dune bluffs of Mason County, and the loess hills that border the Mississippi River above Rock Island and the Sangamon River in Cass County. Published descriptions by Gleason (1910) and others and our own personal observations of all these areas show the difference, which is defined here, very clearly. The flora of the crest of the bluffs is the same as that of the crest of the hills. These two situations are similar as to exposure to wind and sun and as to porosity of soil. They are both without loess and, though different as to the origin of the soil, they both have a coarse gravel that is so similar as to suggest a possible correlation with the similar plant species of the two crests.

The Dominant Species

The constant grasses on the crests are the mid-height grasses, little bluestem, prairie dropseed, and sideoats grama, which are found on all true prairies. June grass, a common mid-height, dry-prairie grass, is abundant only on the bluffs opposite

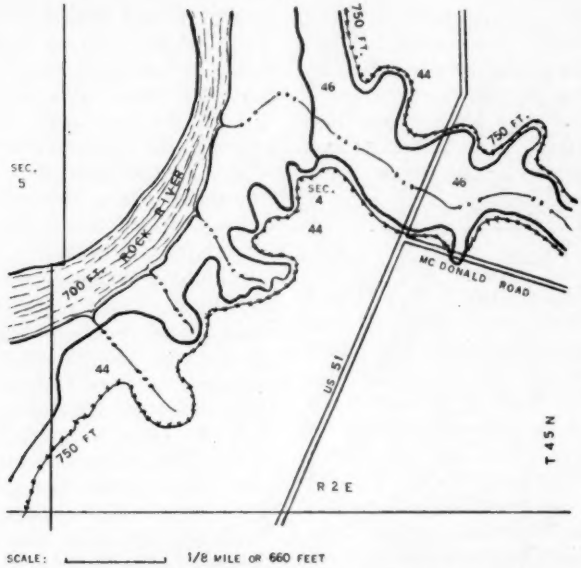

FIG. 2.—Soils of Roscoe terrace bluff: soil 44, O'Neill sandy loam; soil 46, Hickory gravelly loam.

Rockton and in the Camp Grant area where there is a large sand content in the soil. There is not enough moisture for turkey-foot and Indian grass except in draws and damp spots. Switch grass is limited to the more sandy places, and porcupine grass is very irregularly distributed. Cord grass does not occur. The understory is of *Aristida* spp., low panicums, *Leptoloma cognatum* and *Eragrostis spectabilis*, the short plains grasses being absent.

The most important constant forb is the pasque flower which grows on all the hills, often abundantly, and, being usually absent from other prairies, can be considered an indicator of this type in much the same way that *Oenothera rhombipetala* indicates sand, *Valeriana edulis*, wet, and *Silphium laciniatum*, high prairie. Other constant forbs that are not so strictly limited to gravel hills are: *Carex umbellata; Ranunculus rhomboideus; Linum sulcatum; Amorpha canescens; Androsace occidentalis; Acerates lanuginosa; Penstemon pallidus; Synthyris bullii; Campanula intercedens; and Liatris cylindracea.* These are all noteworthy plants, but it is the kind and frequency of the secondary species that give the hills their distinctive character. These secondary plants vary from place to place. To get a clear picture, the series of hills and bluffs must be considered a unit, since many of the unusual plants are now so rare as to be found only in one or, at the most, a few small areas. Examples are western species

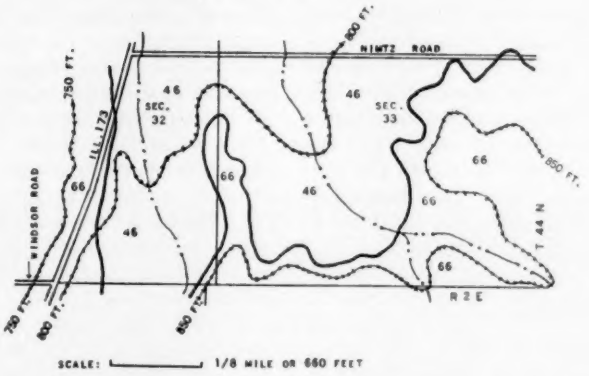

FIG. 3.—Soils of Byron Easton hill: soil 46, Hickory gravelly loam; soil 66, Durand sandy loam.

such as *Gentiana quinquefolia* var. *occidentalis, Gerardia gattingeri, Lactuca ludoviciana, Castilleja sessiliflora,* some artemisias, and northern or northwestern species such as *Panicum wilcoxianum, Carex richardsonii, Geum triflorum, Gentiana puberula, Gerardia aspera, Aster ptarmicoides,* and *Agoseris cuspidata.* None of these is constant on all the hills but all are rare or absent elsewhere in the area.

THE SOILS

Our thanks are due Lyle B. Palmer and Glen D. Greek of the Winnebago County Soil Conservation District for the following data on soils. The maps are adapted from Soil Service Aerial Maps.

Figure 2 is a soil map of the terrace bluff south of Roscoe (area B, Fig. 1), selected because of its comparatively undisturbed condition. Figure 3 is a similar map of the Byron Easton hill (area C, Fig. 1), a considerable part of which has never been plowed or excessively grazed. These maps show the crests to have the same soil, Hickory gravelly loam (Wascher, *et al.*, 1950), the gravel being more dominant on the Roscoe bluff, where it is water-lain (Fig. 6), than on the Easton hill, where it is glacial till (Fig. 4). Both these areas have a prairie vegetation of the type described here. Back from the crest of the bluff, O'Neill sandy loam, a water-lain soil, supports a dry, sandy-prairie vegetation, whereas back of the hill crest is a high-prairie growth on Durand sandy loam, till on dolomite bedrock, which, to the east, grades into the transition belt mentioned above.

The growths on O'Neill sandy loam (Fig. 7) and on Durand sandy loam (Fig. 5) are similar. Both have thick stands of mid-height and some taller grasses, and the understory is well developed. The ground is completely covered, the grass bunches and the forb stems being close together. The species differ somewhat,

apparently because of the finer sand content of O'Neill. *Sporobolus cryptandrus* and *S. vaginiflorus* on O'Neill take the place of *S. asper* and *S. neglecta* on Durand. *Panicum virgatum* is expected on O'Neill, but *Stipa* is more likely on Durand. *Potentilla recta* is common on O'Neill and *P. arguta* on Durand. We have noted many such differences in the tabulation of species. The similarities and differences in the plants found on O'Neill and on Durand sandy loam are interesting but not well enough marked to constitute a unique characteristic; it is likely that such relationships are quite common.

On the soil called Hickory the lines are much more defined. There is some difference in this soil in the two situations but not enough to justify a division into two types or, apparently, to make a difference in the species which inhabit the two areas. The species are surprisingly similar in spite of the finer sand and coarser gravel of the Roscoe bluff. We are not able to place any significance on the fact that *Houstonia* is absent from the Easton hill or upon the abundance of *Polanisia, Penstemon pallidus,* and *Carex heliophila* on the Roscoe bluff.

On Hickory gravelly loam (Figs. 4 and 6) there are no tall grasses; the cover of mid-height grasses and the understory of panicums and *Aristida* is sparse, and the interspaces are large. The forbs are low-growing, deep-rooted perennials like pasque flower, *Castilleja, Liatris cylindracea,* and *Agoseris cuspidata.* Taller species such as *Brauneria,* little bluestem, *Aster cordifolius,* and *Artemisia caudata* (here often perennial), when growing on Hickory soil are depauperate. Interstitials like *Festuca octoflora, Polygonum tenue,* and *Linum sulcatum* are few, their place being taken by low mat-formers like *Carex* spp., *Arenaria stricta, Geum triflorum, Potentilla argentea, Androsace occidentalis, Antennaria* spp., and others. There is a scant growth of mosses and lichens on the bare interspaces which, because of the porous soil, are not greatly eroded. Flowering of the forbs comes early on Hickory soil, apparently not to avoid the threat of shade from the developing grasses, but to complete the blooming cycle while moisture is available. It is particularly here that the pasque flower grows, and it is only here that *Castilleja sessiliflora, Gerardia gattingeri, Agoseris cuspidata,* and some of the other secondary dominants are found.

It cannot be doubted that this combination of gravel soil and exposed location forms the optimum habitat for the pasque flower and its associates, but whether the relationship is one of soil, of microclimate, or of both is not so clear. Some of the species occur, in our experience, only on this soil, but others, notably *Carex umbellata,* pasque flower, *Ranunculus rhomboideus, Synthyris bullii,* and *Gerardia aspera,* are found at times on high, rolling or sand prairies in Winnebago, Boone and Ogle counties, where the climatic conditions, but not the soil, are like those of our gravel prairies. On the other hand many species, such as *Campanula intercedens, Arenaria stricta, Arabis pycnocarpa,* and *Houstonia lanceolata,* do not require an exposed location but do need a gravel or rocky soil or a rock outcrop to take its

place. This is apparent on some of the "limestone prairies" that are not exposed and some of which have an abundance of pasque flowers and many of the other species.

Seasonal Changes

About April 1, though the ground is still frozen in protected spots and there is still some snow and ice in the draws, the pasque flower blooms

Fig. 4.—Byron Easton hill (area C, Fig. 1); Hickory gravelly loam (soil 46, Fig. 3).

Fig. 5.—Byron Easton hill (area C, Fig. 1); Durand sandy loam (soil 66, Fig. 3).

and is followed very soon by the red patches of *Geum triflorum* and the new growth of *Arenaria stricta*. Then three sedges begin to flower, *Carex pennsylvanica, C. umbellata,* and *C. richardsonii,* the latter being very conspicuous during the short time it is in bloom. Then come *Draba reptans, Androsace occidentalis,* the two early buttercups, *Ranunculus fascicularis* and *R. rhomboideus,* and *Carex meadii.* The rosettes of *Solidago nemoralis* and *Artemisia caudata* are distinguishable. The prairie willow blooms before the earliest violets, *Viola pedata* and *V. pedatifida,* begin to flower.

During May the spring flowers

FIG. 6.—Roscoe terrace bluff (area B, Fig. 1); Hickory gravelly loam (soil 46, Fig. 2).

FIG. 7.—Roscoe terrace bluff (area B, Fig. 1); O'Neill sandy loam (Soil 44, Fig. 2).

complete their blooming cycle. Some of the less common are *Castileja sessilifloria, Houstonia lanceolata, Acerates lanuginosa,* and *Campanula intercedens. Ceanothus ovatus,* very rare, flowers before June 1 when the grasses begin to take over. The low panicums, some of which are not found elsewhere in the county, are on all the hills. They and *Koeleria cristata,* which is plentiful on some hills, are in flower at the same time as *Carex brevior, C. tenera,* and *C. normalis.* None of these is tall enough to interfere with the many early forbes which cover the hills at this time. As the season advances and the grasses cause more shade the forbs are those species which are taller and more robust.

The first of the typical summer grasses is *Stipa spartea,* which, though not always present on the hills, is abundant in places. The tall grasses, turkeyfoot and Indian grass, are absent from some of the hills and on many others occur only in draws and damp spots, particularly in disturbed areas. The quack grasses are not abundant. Blue grasses, particularly *Poa compressa,* invade some draws to the exclusion of other growth. The annual panicums, *P. capillare* and *P. dichotomoflorum,* appear as invaders from contiguous fields. *Elymus* is not plentiful. *Setaria* spp., *Agrostis hyemalis, Hordeum jubatum,* and some introduced bromes are all of minor importance, though conspicuous in some spots. The same is true of *Eragrostis,* except the perennial, *E. spectabilis,* and the annual, *E. pectinacea,* which are abundant in places. Important in late summer are *Sporobolus asper, S. drummondi,* and *S. heterolepis, Leptoloma cognatum,* and *Aristida basiraema,* and *A. oligantha.*

Important summer forbs are: *Potentilla arguta*; *Asclepias verticillata* which is in weedy abundance on some hills that were formerly grazed; *Asclepias amplexicaulis* which is less frequent than on sand; *Acerates viridiflora* which is uncommon; *Verbena stricta; V. simplex; Liatris aspera;* several goldenrods; and *Coreopsis palmata.* All these are tall enough to compete with the grasses. The small interstitials which will stand some shade are: *Polygonum tenue, Mollugo, Chamaesyce* spp., *Linum sulcatum, Lechea stricta, Physalis heterophylla, Gerardia aspera, G. gattingeri,* and *Ruellia humilis.* Other common summer plants are *Heuchera richardsonii, Petalostemum purpureum, P. candidum, Lespedeza capitata, L. hirta* abundant opposite Rockton and in the Camp Grant area, and *Kuhnia eupatorioides* which is less common than on many prairie roadsides. *Hypericum punctatum* is an occassional vigorous invader. As the grasses mature in late summer a number of asters and several species of *Artemisia* become conspicuous. *Heliopsis, Ratibida pinnata, Helianthus occidentalis, H. rigidus,* and *H. grosseserratus* are all less common than on other types of dry prairie as are also the silphiums and the prairie eupatoriums.

Woody plants beside those mentioned include: occasional small junipers, Iowa crab in small clumps, and infrequent blackberry patches, *Rosa humilis;* all are less frequent than on high prairies. *Rhus glabra, Symphoricarpos occidentalis,* and *S. orbiculatus* are uncommon.

The autumnal aspect is of matured

grasses and of taller forbs going to seed. The asters are disappearing and the only additional plant of consequence is the prairie gentian which is irregularly distributed.

Winter presents only windswept hills covered with old grass stems most of which can still be identified next spring.

Individual Patches

The following small tracts are of particular interest. Some are worth preserving in their natural condition. This is something that deserves immediate attention (Fig. 1).

A. The bluff west of Rockton has such unusual plants as *Gerardia gattingeri, Symphoricarpos orbiculatus, Artemisia dracunculoides,* and *Agoseris cuspidata.*

B. The flora of the bluffs that closely border Rock River for about two miles from the south edge of Roscoe is well preserved. Here on the crest, *Houstonia lanceolata* grows abundantly as do *Ranunculus rhomboideus, Synthyris bullii, Penstemon pallidus, Polanisia graveolens, Arenaria stricta,* and *Carex heliophila. Geum triflorum* is uncommon and *Gentiana puberula* apparently absent.

C. On the Byron Easton hill at the east end of Windsor road on Illinois highway 173 are about 20 acres constituting the best preserved of the series of prairie patches. Here grow: *Castilleja sessiliflora; Carex richardsonii; C. abdita; C. umbellata; Panicum wilcoxianum; P. perlongum; Aster ptarmicoides; Cirsium hillii;* and many others. *Carex meadii* is abundant on one ridge.

D. On the hill north of the Forest Hills Country Club a few years ago, pasque flowers were in almost pure stands over areas of several square rods. Though much of the hill has been built upon there is still an abundance of the plants which characterize the gravel-hill prairies.

E. The persistence of prairie plants in adverse situations is shown on the 40-foot bluff north of the mouth of Keith Creek near where Rockford College was built in 1847. The following prairie species are still in evidence here after more than a century of urbanization: *Sorghastrum nutans; Bouteloua curtipendula; Elymus canadensis; Sporobolus asper; Panicum scribnerianum; Mira bilis nyctaginea; Draba reptans; Poinsettia heterophylla; Androsace occidentalis; Oenothera laciniata; Solidago glaberrima; Aster oblongifolius; Aster ericoides;* and *Aster pilosus.*

F. The hill at 18th avenue and the Chicago and Northwestern railway in East Rockford has *Ceanothus ovatus, Acerates lanuginosa, Liatris cylindracea,* several asters, and *Brauneria pallida.*

G. The hill at 20th street and the Illinois Central railroad in East Rockford has an unusual amount of *Stipa spartea* and other high prairie plants.

H. Silver Hill, south of Harrison avenue and east of 11th street in Rockford, has, for the most part, been disturbed by building activities, but many out-of the-way places have kept the original gravel-hill flora. *Lespedeza capitata, L. hirta, Liatris aspera,* and *Brauneria pallida* thickly cover large areas.

I. The bluff flora at the Sanitary District Plant has been greatly disturbed but two small areas are still in good condition. One north of the

plant has prairie and sand dropseed, the bluestems, Indian grass, and sideoats grama forming a thick mat over the steep hillside. On the wooded part of the bluff south of the plant is *Carex X fulleri* H. E. Ahles, found in 1949 and which is not known elsewhere.

J. A gravel-bluff prairie in Camp Grant where sandy flat prairies are the rule has *Panicum virgatum* in large clumps and an abundance of *Oenothera rhombipetala*. *Anemone caroliniana* and *Agoseris cuspidata* grow here.

Tabulation of the Species

The following species are important on gravel-hill prairies. Many introduced plants and very common natives are not mentioned in the list, but specimens of all plants of the area have been collected and are deposited either in Rockford College Herbarium or in the Illinois State Museum. We did not attempt to collect each plant from every hill because to do so would require much labor of little value. Quadrat counts were not made because the selection of quadrats in these small, widely separated patches would be so subjective as to preclude the formulation of any objective conclusions.

Symbols Used in Tabulation

Column 1: 1, rare; 2, uncommon; 3, common; 4, abundant.

Column 2: M, mat; P, patch; I, interstitial; B, bunch; S, single stem.

Column 3: V, spring; S, summer; A, fall.

Column 4: T, more than one foot; L, less than one foot.

Column 5: 1, only on Hickory soil and there rare; 2, common on Hickory soil, less common on O'Neill and Durand; 3, all prairies, more often on Hickory soil but also on O'Neill and Durand; 4, all, but most often on sand prairies; 5, all, but most often on high flat or rolling prairies; 6, all, but most often on low prairies or in damp places on other prairies; 7, adventive or with no apparent soil preference.

TABLE 1.—List of Species.

	Frequency	Growth form	Flowering season	Height	Soil preference
Equisetum arvense, horsetail	3	S	V	L	6
hyemale, scouring rush	2	P	S	T	5
Juniperus virginiana, red cedar	2	S	S	T	5
Bromus (introd. spp.), brome grass	2	I	V	L	7
Festuca octoflora, slender fescue	3	I	S	L	4
Poa compressa, Canada bluegrass	3	M	V	L	6
pratensis, Kentucky bluegrass	4	M	V	L	6
Eragrostic cilianensis, stink-grass	2	I	S	L	7
pectinacea, love-grass	3	I	S	L	5
spectabilis, tumble-grass	3	B	S	L	5
Agropyron repens, quackgrass	2	P	S	T	5
smithii, western quackgrass	2	P	S	T	5
Elymus canadensis, wild rye	2	S	S	T	5
virginicus, wild rye	2	S	S	T	6
Hordeum jubatum, squirrel-tail	3	I	S	L	5
Koeleria cristata, June-grass	2	B	V	T	4
Agrostis alba, redtop	2	M	S	L	7
hyemalis, ticklegrass	3	I	S	L	5
Sporobolus asper, dropseed	3	B	S	T	5
cryptandrus, sand dropseed	2	B	S	T	4
heterolepis, prairie dropseed	3	B	S	T	3
neglectus, annual dropseed	2	I	S	L	5
vaginiflorus, annual dropseed	3	I	S	L	4
Stipa spartea, porcupine-grass	2	S	V	T	4
Aristida basiramea, three-awn grass	3	I	S	L	5
oligantha, three-awn grass	3	I	S	L	5
Bouteloua curtipendula, side-oats grama	3	B	S	T	5
Leptoloma cognatum, fall witch-grass	3	B	S	L	5
Panicum capillare, witch-grass	3	I	S	L	7
depauperatum	2	B	S	L	5
dichotomoflorum	2	I	S	L	7
implicatum	3	I	S	L	5
meridionale	2	M	S	L	5
oligosanthes	1	S	S	L	5
perlongum	3	B	S	L	5
pseudo-pubescens	3	M	S	L	4
scribnerianum	3	S	S	L	3
virgatum, switch-grass	2	B	S	T	4
wilcoxianum	1	M	S	L	1
Setaria lutescens, fox-tail	3	S	S	T	5
viridis, fox-tail	3	S	S	T	5
Andropogon gerardi, big bluestem	3	B	S	T	6
scoparius, little bluestem	4	B	S	T	5
Sorghastrum nutans, Indian grass	2	B	S	T	6
Cyperus filiculmis	2	S	S	L	4
schweinitzii	2	S	S	L	4
Carex abdita	1	M	V	L	3
brevior	2	B	S	L	5
gravida	3	B	S	L	5
heliophila	1	M	V	L	3

TABLE 1.—List of Species—Continued.

meadii	2	S	V	L	5
normalis	2	B	S	L	5
pennsylvanica	2	M	V	L	5
richardsonii	1	M	V	L	1
tenera	2	B	S	L	6
tetanica	1	S	V	L	6
umbellata	1	M	V	L	3
Commelina communis, day-flower	2	M	V	L	7
Tradescantia ohioensis, widow's-tears	2	S	V	T	7
Juncus interior, rush	1	B	S	L	5
tenuis, common rush	2	M	S	L	7
Polygonatum commutatum, Solomon's seal	1	S	S	T	7
Smilax hispida, greenbrier	1	S	S	T	7
lasioneuron, carrion-flower	1	S	S	T	7
Hypoxis hirsuta, stargrass	1	I	V	L	6
Sisyrinchium albidum, blue-eyed grass	3	M	V	L	5
montanum, blue-eyed grass	2	M	V	L	6
Populus tremuloides, quaking aspen	2	S	V	T	6
Salix humilis, prairie willow	3	P	V	T	5
Comandra umbellata, toadflax	3	I	V	L	6
Rumex acetosella, sour-dock	2	M	S	L	7
Polygonum tenue	2	I	S	L	4
Mirabilis nyctaginea, wild four-o'clock	1	S	S	T	5
Mollugo verticillata, carpet-weed	3	I	S	L	7
Stellaria media, chickweed	2	M	S	L	7
Arenaria lateriflora, sandwort	2	M	V	L	7
serpyllifolia, sandwort	2	M	V	L	7
stricta, rock sandwort	2	M	V	L	3
Silene antirrhina, sleepy catchfly	3	S	V	L	5
Saponaria officinalis, bounding Bet	3	P	S	T	7
Aquilegia canadensis, columbine	2	S	S	T	6
Ranunculus fascicularis, buttercup	3	M	V	L	5
rhomboideus, buttercup	2	M	V	L	5
Anemone caroliniana, anemone	1	I	V	L	1
cylindrica, thimbleweed	2	S	S	T	5
ludoviciana, pasque flower	1	S	V	L	3
virginiana, thimbleweed	2	S	S	T	3
Corydalis flavula, pale corydalis	1	M	S	L	3
Draba reptans	3	I	V	L	5
Arabis pycnocarpa, rockcress	2	S	S	T	3
Polanisia graveolens, clammyweed	2	S	S	T	3
Heuchera richardsonii, alumroot	2	S	S	T	6
Fragaria virginiana, strawberry	2	M	V	L	6
Potentilla argentea, silvery cinquefoil	2	M	S	L	5
arguta, tall cinquefoil	2	S	S	T	5
monspeliensis, rough cinquefoil	2	S	S	T	5
recta, cinquefoil	2	S	S	T	4
simplex, cinquefoil	2	S	S	L	6
Geum triflorum, prairie smoke	2	M	V	L	3
Rubus alleghensiensis, blackberry	1	P	S	T	7
flagellaris, dewberry	1	P	S	L	7
occidentalis, black raspberry	1	P	S	T	7
Rosa carolina, wild rose	1	P	S	T	5
eglanteria, sweetbrier	1	P	S	T	7
suffulta, prairie rose	2	P	S	L	5
Malus ioensis, Iowa crab	2	S	S	T	6
Crataegus mollis, redhaw	1	S	V	T	6
Prunus americanus, wild plum	2	P	V	T	6
virginiana, choke-cherry	1	P	S	T	5
Baptisia leucantha, wild indigo	2	S	S	T	5
leucophoea, wild indigo	2	S	S	T	5
Trifolium arvense, rabbit-foot clover	2	I	S	L	7

Soil preference

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TABLE 1.—List of Species—Continued.

Amorpha canescens, lead-plant	3	P	S	T	3
Petalostemum candidum, prairie clover	2	P	S	T	5
purpureum, prairie clover	3	P	S	T	5
Desmodium canadense, tick-clover	2	S	S	T	5
canescens, tick-clover	2	S	S	T	5
illinoense, tick-clover	1	S	S	T	4
Lespedeza capitata, bush-clover	3	S	S	T	5
hirta, bush-clover	3	S	S	T	5
longifolia, bush-clover	1	S	S	T	3
Oxalis violacea, wood-sorrel	2	I	S	L	3
Linum sulcatum, yellow flax	2	I	S	L	3
Ptelea trifoliata, wafer-ash	2	S	S	T	7
Polygala verticillata, milkwort	1	I	S	L	5
Chamaesyce glyptosperma, spurge	1	I	S	L	4
maculata, spurge	2	I	S	L	5
supina, spurge	3	I	S	L	5
Euphorbia corollata, flowering spurge	3	S	S	T	5
dentata	2	S	S	T	5
Poinsettia heterophylla	1	S	S	T	3
Celastrus scandens, bittersweet	2	S	S	T	7
Rhus glabra, smooth sumac	2	S	S	T	7
radicans, poison ivy	1	P	S	T	6
Ceanothus americanus, New Jersey tea	2	S	S	T	5
ovatus, New Jersey tea	1	S	V	T	5
Hypericum perforatum, St. John's-wort	2	P	S	T	7
pseudomaculatum, St. John's-wort	2	P	S	T	4
sphaerocarpum, St. John's-wort	1	P	S	T	6
Helianthemum canadense, frostweed	2	S	S	T	5
bicknellii, frostweed	2	S	S	T	4
Lechea stricta, pinweed	2	S	S	T	5
tenuifolia, pinweed	2	M	S	L	4
Viola fimbriatula, sand violet	2	S	V	L	4
papilionacea, butterfly violet	3	M	V	L	6
pedata, bird-foot violet	2	M	V	L	4
pedatifida, prairie violet	2	S	V	L	5
Viola X bernardi	1	S	V	L	5
Oenothera biennis, evening primrose	3	S	S	T	7
laciniata, evening primrose	1	S	S	T	4
rhombipetala, evening primrose	2	S	S	T	4
Gaura biennis, butterfly-weed	3	S	S	T	6
Eryngium yuccifolium, rattlesnake-master	2	S	S	T	6
Zizia aurea, golden Alexanders	2	S	S	T	6
aptera, golden Alexanders	2	S	S	T	6
Taenidia integerrima, yellow pimpernel	2	S	S	T	5
Thaspium barbinode, meadow parsnip	1	P	S	T	6
trifoliatum, meadow parsnip	3	P	S	T	6
Androsace occidentalis	2	M	V	L	3
Lysimachia lanceolata, loosestrife	2	P	S	L	5
Dodecatheon meadia, shooting-star	3	S	V	L	6
Gentiana puberula, prairie gentian	2	S	A	L	5
quinquefolia var. *occidentalis*	1	I	A	L	3
Apocynum cannabinum, Indian hemp	2	P	S	T	6
Asclepias amplexicaulis, milkweed	2	S	S	L	4
sullivantii, milkweed	2	S	S	T	6
syriaca, milkweed	3	S	S	T	6
tuberosa, butterfly-milkweed	1	S	S	T	4
verticillata, horsetail milkweed	3	S	S	T	5
Acerates lanuginosa	1	S	S	L	3
viridiflora, green milkweed	1	S	S	T	4
Phlox pilosa, prairie phlox	3	S	S	T	6
Lithospermum angustifolium, puccoon	3	S	S	T	5
canescens, puccoon	2	S	S	L	5

TABLE 1.—List of Species—Continued.

croceum, puccoon	2	S	S	L	4
Verbena bracteata	3	M	S	L	7
simplex, vervain	2	S	S	T	4
stricta, hoary vervain	3	S	S	T	5
Isanthus brachiatus, false pennyroyal	2	S	S	L	3
Scutellaria parvula, skullcap	2	I	S	L	3
leonardi, skullcap	1	I	S	L	3
Physostegia virginiana, false dragonhead	2	S	S	T	5
Glecoma heterophylla, ground-ivy	1	M	S	L	7
Prunella vulgaris, carpenter's-weed	2	S	S	L	7
Leonurus cardiaca, motherwort	2	S	S	T	7
Monarda fistulosa, wild bergamot	3	P	S	T	5
Hedeoma hispida, rough pennyroyal	4	S	S	L	4
Pycnanthemum virginianum, mountain mint	3	B	S	T	5
Solanum carolinense, horse-nettle	2	S	S	L	4
dulcamara, deadly nightshade	2	S	S	T	7
nigrum, black nightshade	3	S	S	L	7
Physalis heterophylla, ground-cherry	3	S	S	T	5
subglabrata, ground-cherry	2	S	S	T	5
virginiana, ground-cherry	1	S	S	T	4
Veronica arvensis, speedwell	2	I	S	L	3
Synthyris bullii, kitten-tails	1	S	S	T	3
Gerardia aspera	1	I	A	L	1
gattingeri	1	I	A	L	1
Castilleja sessiliflora	1	S	V	L	1
Penstemon pallidus, beard-tongue	2	S	S	L	2
Ruellia humilis, wild petunia	3	M	S	L	5
Plantago aristata, bracted plantain	2	I	S	L	4
purshii	1	I	S	L	5
Houstonia lanceolata, bluets	1	M	S	L	2
Symphoricarpos occidentalis, wolfberry	1	P	S	T	5
orbiculatus, coral-berry	1	P	S	T	5
Campanula intercedens, harebell	2	B	V	L	3
Triodanis perfoliata, Venus' looking-glass	3	I	V	L	4
Lobelia inflata, Indian tobacco	2	I	S	T	7
spicata	2	I	S	T	6
Ambrosia coronopifolia, western ragweed	2	S	S	T	7
elatior, common ragweed	3	S	S	T	5
Vernonia fasciculata, iron-weed	2	S	S	T	6
Eupatorium altissimum, boneset	2	S	S	T	5
serotinum, boneset	2	S	S	T	5
rugosum, white snake-root	2	S	S	T	7
Kuhnia eupatorioides, false boneset	3	S	S	T	5
Liatris aspera, blazing-star	3	S	S	T	5
cylindracea, blazing-star	2	S	S	L	2
Solidago altissima, goldenrod	3	S	S	T	6
gigantea, goldenrod	3	S	S	T	6
glaberrima, prairie goldenrod	3	P	S	T	5
juncea, early goldenrod	2	P	S	T	6
media, goldenrod	2	P	S	T	5
nemoralis, goldenrod	3	S	S	T	3
rigida, stiff goldenrod	2	S	A	T	5
speciosa, showy goldenrod	2	P	A	T	5
Aster cordifolius, aster	3	S	S	T	3
ericoides, heath aster	2	P	A	T	5
exiguus, heath aster	2	P	A	T	5
laevis, smooth aster	2	S	A	T	5
linariifolius, aster	2	S	A	T	4
novae-angliae, New England aster	2	S	A	T	6
oblongifolius, aster	1	P	A	T	5
pilosus, aster	3	S	A	T	5
ptarmicoides, aster	1	S	A	T	2

TABLE 1.—List of Species—Concluded.

sericeus, silky aster	2	I	A	T	5
Erigeron annuus, daisy fleabane	2	S	S	T	7
canadensis, fleabane	3	S	S	T	7
strigosus, daisy fleabane	3	S	S	T	7
Antennaria neglecta, pussy-toes	3	M	V	L	5
neodioica, pussy-toes	3	M	V	L	5
Gnaphalium obtusifolium, everlasting	2	S	S	T	7
Silphium integrifolium, rosin-weed	2	P	A	T	5
laciniatum, compass-plant	2	S	A	T	5
terebinthinaceum, prairie-dock	2	S	A	T	6
Heliopsis helianthoides, ox-eye	3	S	S	T	5
Rudbeckia hirta, blackeyed Susan	3	S	S	T	6
serotina var. *lanceolata*	2	S	S	T	5
triloba, browneyed Susan	2	S	S	T	7
Brauneria pallida, purple cone-flower	3	S	S	T	5
Ratibida pinnata, pale cone-flower	3	S	S	T	5
Helianthus grosseserratus, sun-flower	2	S	S	T	5
occidentalis, sun-flower	2	P	S	T	5
petiolaris, annual sun-flower	2	S	S	T	5
rigidus, sun-flower	2	S	S	T	5
Coreopsis palmata, tickseed	2	P	S	T	5
Bidens vulgata, beggar-ticks	2	S	S	T	7
Helenium autumnale, sneezeweed	2	S	A	T	6
Achillea millifolium, yarrow	3	S	S	T	7
Artemisia caudata, wormwood	2	S	S	T	4
gnaphaloides, white sage	2	S	S	T	5
ludoviciana, white sage	2	S	S	T	5
dracunculoides, wormwood	1	S	S	T	5
Cirsium hillii, Hill's thistle	1	S	S	T	3
Centaurea maculosa, knapweed	2	P	S	T	7
Tragopogon pratensis, goat's-beard	2	S	V	T	7
Cichorium intybus, blue-sailors	2	P	S	T	7
Lactuca ludoviciana, wild-lettuce	1	S	S	T	5
Prenanthes aspera, white lettuce	1	S	S	T	5
racemosa, white lettuce	1	S	S	T	6
Hieracium canadense, hawkweed	1	S	S	T	5
longipilum, hawkweed	2	S	S	T	5
Agoseris cuspidata	1	S	S	L	1

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A CHECK-LIST OF ILLINOIS MYXOMYCETES

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Introduction

The Mycological Collections of the Department of Botany Herbarium, University of Illinois, contained, prior to the present study, only a small number of specimens of Myxomycetes from Illinois. Most of these had been collected late in the 19th century by Professor T. J. Burrill and his students, principally G. P. Clinton and A. B. Seymour. John Wolf, an early Illinois naturalist, collected actively in the 1870's in the region around Canton, Illinois, and a few of his specimens are now preserved in the collections of the University of Illinois.

The earliest published reference to Myxomycetes in Illinois appears to be that of Brendel (1887) who listed two specimens from the vicinity of Peoria. The first edition of Macbride's monograph of the slime-moulds (1899) cited about 20 species collected in Illinois. Many of the collections made by Burrill and his students were referred to Macbride for identification. An examination of the Myxomycetes collection in the Herbarium of the State University of Iowa, where Macbride's specimens are on deposit, has failed to reveal any specimens collected by him in Illinois. Monographs (Hagelstein, 1944; Lister, 1925; Macbride, 1922; Macbride and Martin, 1934; Martin, 1949) published since the first edition of Macbride (1899) add little specific information to a knowledge of the occurrence of Myxomycetes in Illinois.

Stover (1941) published a check-list of 36 species of Myxomycetes collected in Coles and Clark counties. Unfortunately the specimens on which this paper was based have been partially destroyed through continued use as classroom material. Professor Stover kindly permitted the writer to examine his specimens, and a portion of several of these was given to the author. These specimens have been deposited in the University of Illinois Herbarium and are cited later.

The present study was begun during the spring of 1947 and continued through the spring of 1951 when weather conditions were favorable. Collecting was confined for the most part to Champaign County but also was pursued in a number of other localities in the state.

Extensive work with moist chamber cultures in the laboratory using the methods first suggested and employed successfully by Gilbert and Martin (1933) supplemented the collection of specimens in the field. Small samples of bark cut from living trees were placed in Petri dishes and kept moist for a period of days or weeks. In this manner several minute species including, for example, *Echinostelium minutum, Comatricha cornea, C. fimbriata, Macbrideola decapillata,* and *M. scintillans,* were obtained. Such species

are nearly impossible to observe in the field.

During the period of this study about 550 collections were studied. These include 125 species belonging to 33 genera of Myxomycetes collected by the author and, with the addition of species collected by students other than the writer, the enumeration given below includes 133 species in 35 genera. This represents 43% of all species and all but 9 of the genera of Myxomycetes which have been reported as occurring in North America (Alexopoulos and Beneke, 1954; Benjamin and Poitras, 1950; Martin, 1949; Welden, 1954). All specimens cited are on deposit in the Herbarium of the Department of Botany, University of Illinois.

In order to conserve space in the citation of specimens examined, the following code will identify those localities from which the majority of collections was obtained:

U=immediate vicinity of Champaign and Urbana, Champaign Co., Illinois.

BW=Brownfield Woods, a tract of woodland owned and maintained by the University of Illinois and located approximately three miles northeast of Urbana.

TW=Trelease Woods, also a tract of woodland owned by the University of Illinois, and located approximately four miles east of Urbana.

Collections made in other localities are cited in full in the text. Unless otherwise stated, all collections were made by the writer.

The system of classification of Martin (1949) is used in this paper, and only the name accepted as valid by Martin is cited here. The reader is referred to this readily available and indispensable work for synonymy, complete biblography, references to illustrations, and data on the further distribution in North America of the species listed. Lister's monograph (1925) is especially useful to the student of the slime-moulds because of its numerous illustrations —many of them in color.

The greater portion of this paper is based on a thesis (Benjamin, 1949) presented by the writer to the faculty of the University of Illinois in partial fulfillment of the requirements for the degree of Master of Science in the Department of Botany.

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The author is greatly indebted to Dr. Leland Shanor for his advice and encouragement during the course of this study, to Dr. G. W. Martin for his aid in checking some questionable determinations and for his advice and help during my study of Illinois collections contained in the Myxomycete Herbarium of the State University of Iowa, and to Dr. E. L. Stover who kindly permitted me to examine his collections at Eastern Illinois State College.

Systematic Arrangement of Species Collected

CERATIOMYXALES

Ceratiomyxaceae

1. *Ceratiomyxa fruticulosa* (Muell.) Macbr. U; BW; TW; Canton, Fulton Co., John Wolf; Grantsburg, Johnson Co.; Havana, Mason Co., T. J. Burrill.

LICEALES

Liceaceae

2. *Licea biforis* Morgan. BW.
3. *Licea kleistobolus* Martin. U; Wyanet, Bureau Co.
4. *Licea parasitica* (Zukal) Martin. Kickapoo State Park, Vermilion Co.
5. *Licea minima* Fries. U; BW.
6. *Licea tenera* Jahn. U.
7. *Tubifera ferruginosa* (Batsch) Gmelin. U; BW; Canton, Fulton Co., John Wolf.
8. *Tubifera microsperma* (Berk. and Curt.) Martin. U; BW.

Reticulariaceae

9. *Lycogala conicum* Pers. TW.
10. *Lycogala epidendrum* (L.) Fries. U; BW; Mahomet, Champaign Co.; Gale, Alexander Co.; Canton, Fulton Co., John Wolf; Belknap (A. B. Seymour) and Grantsburg, Johnson Co.; Yorkville, Kendall Co.; Havana, Mason Co., coll. unknown.
11. *Lycogala exiguum* Morgan. BW.; Starved Rock State Park, La Salle Co.
12. *Lycogala flavofuscum* (Ehrenb.) Rost. U, Gibbs and Clinton; BW; 5 mi. N.W. Kankakee, Kankakee Co.
13. *Dictydiaethalium plumbeum* (Schum.) Rost. U; BW; 2 mi. W. Fifer, McLean Co.
14. *Reticularia lycoperdon* Bull. U; BW; Mahomet, Champaign Co.; Yorkville, Kendall Co.; Havana, Mason Co., G. P. Clinton.
15. *Enteridium rozeanum* (Rost.) Wingate. U; Canton, Fulton Co., John Wolf.

Cribrariaceae

16. *Cribraria intricata* Schrad. BW; Starved Rock State Park, La Salle Co.
17. *Cribraria microcarpa* (Schrad.) Pers. U; BW.
18. *Cribraria minutissima* Schw. U.
19. *Cribraria tenella* Schrad. BW; TW.
20. *Cribraria violacea* Rex. BW; 2 mi. N.W. Monticello, Piatt Co.; Mount Pleasant, Union Co.
21. *Dictydium cancellatum* (Batsch) Macbr. U; BW; 1 mi. S. Gale, Alexander Co.; 1 mi. E. Grantsburg, Johnson Co.; Havana, Mason Co., G. P. Clinton.

TRICHIALES

Trichiaceae

22. *Perichaena chrysosperma* (Currey) Lister. U; Apple River Canyon State Park, Jo Daviess Co.
23. *Perichaena corticalis* (Batsch) Rost. TW.
24. *Perichaena depressa* Libert. U; Oak Park, Cook Co.
25. *Perichaena vermicularis* (Schw.) Rost. U.
26. *Arcyria cinerea* (Bull.) Pers. U; 1 mi. S. Gale, Alexander Co.; Canton, Fulton Co., John Wolf; 1 mi. E. Grantsburg, Johnson Co.; Havana, Mason Co., Clinton and Yeakel; 10 mi. N.W. Metropolis, Massac Co.; Kickapoo State Park, Vermilion Co.
27. *Arcyria denudata* (L.) Wettst. U; BW; TW; Starved Rock State Park, La Salle Co.
28. *Arcyria incarnata* (Pers.) Pers. U; BW.
29. *Arcyria insignis* Kalchbr. and Cooke. U; TW.
30. *Arcyria nutans* (Bull.) Grev. U.
31. *Arcyria pomiformis* (Leers) Rost. U; BW.
32. *Oligonema flavidum* (Peck) Peck. 3 mi. N. Mahomet, Champaign Co.; BW; TW; 2 mi. N. Cache, Pulaski Co.; 4 mi. W. Karnak, Pulaski Co.
33. *Oligonema schweinitzii* (Berk.) Martin. U.
34. *Trichia affinis* de Bary. U; BW; TW; Winnebago Co. For. Pre., Winnebago Co.
35. *Trichia contorta* (Ditmar) Rost. U; BW.
36. *Trichia favoginea* (Batsch) Pers. BW; TW; Canton, Fulton Co., John Wolf; Apple River Canyon State Park, Jo Daviess Co.

37. *Trichia persimilis* P. Karst. U; BW; Apple River Canyon State Park, Jo Daviess Co.; Kickapoo State Park, Vermilion Co.
38. *Trichia scabra* Rost. BW; 4 mi. S. Hanover, Jo Daviess Co.; 4 mi. N.W. Eddyville, Polk Co.
39. *Trichia varia* (Pers.) Pers. BW; 2 mi. S. Wheeling, Cook Co.; 3 mi. S. Paxton, Ford Co.; Canton, Fulton Co., John Wolf; 3 mi. S. Morris, Grundy Co.; 4 mi. S. Hanover, Jo Daviess Co.; 5 mi. N.W. Kankakee, Kankakee Co.; Yorkville, Kendall Co.; 4 mi. N.W. Eddyville, Polk Co.
40. *Hemitrichia clavata* (Pers.) Rost. BW; Canton, Fulton Co., John Wolf; Apple River Canyon State Park, Jo Daviess Co.; Clarkville, Macoupin Co., coll. unknown; 4 mi. N.W. Eddyville, Polk Co.
41. *Hemitrichia intorta* (Lister) Lister. Apple River Canyon State Park, Jo Daviess Co.
42. *Hemitrichia serpula* (Scop.) Rost. 5 mi. N. Mahomet, Champaign Co.; BW; Starved Rock State Park, La Salle Co.
43. *Hemitrichia stipitata* (Massee) Macbr. Mahomet, Champaign Co.; U; BW; 1 mi. S. Gale, Alexander Co.; 3 mi. S. Paxton, Ford Co.; 1 mi. E. Grantsburg, Johnson Co.; 3 mi. S. Elburn, Kane Co.; 10 mi. N.W. Metropolis, Massac Co.; 2 mi. N. Cache, Pulaski Co.; 4 mi. W. Karnak, Pulaski Co.
44. *Hemitrichia vesparium* (Batsch) Macbr. U; BW; Canton, Fulton Co., John Wolf; 5 mi. S. Hanover, Jo Daviess Co.; 1 mi. E. Grantsburg, Johnson Co.; Starved Rock State Park, La Salle Co.; Carlinville, Macoupin Co., coll. unknown; Havana, Mason Co., G. P. Clinton; Winnebago Co. For. Pre., Winnebago Co.
45. *Calonema aureum* Morgan. BW; 1 mi. S. Gale, Alexander Co.; 4 mi. W. Karnak, Pulaski Co.

STEMONITALES

Echinosteliaceae

46. *Echinostelium minutum* de Bary. U; 12 mi. W. Geneseo, Henry Co.; 5 mi. W. Buncomb, Johnson Co.; 3 mi. W. Goreville, Johnson Co.; 2 mi. N.W. Monticello, Piatt Co.; Mount Pleasant, Union Co.; Kickapoo State Park, Vermilion Co.

Stemonitaceae

47. *Amaurochaete fuliginosa* (Sow.) Macbr. 8 mi. S.E. Charleston, Coles Co., W. Thomas.
48. *Brefeldia maxima* (Fries) Rost. U, Gibbs and Clinton.
49. *Diachea bulbillosa* (Berk. and Br.) Lister. TW.
50. *Diachea leucopodia* (Bull.) Rost. BW; Charleston, Coles Co., H. Ruck.
51. *Diachea subsessilis* Peck. U.
52. *Enerthenema papillatum* (Pers.) Rost. U; BW.
53. *Stemonitis axifera* (Bull.) Macbr. U; BW; TW; Canton, Fulton Co., John Wolf; 5 mi. W. Buncomb, Johnson Co.; Starved Rock State Park, La Salle Co.
54. *Stemonitis confluens* Cooke and Ellis. TW.
55. *Stemonitis flavogenita* Jahn. U; TW.
56. *Stemonitis fusca* Roth. U; BW; 1 mi. S. Gale, Alexander Co.; 1 mi. E. Grantsburg, Johnson Co.; Starved Rock State Park, La Salle Co.; Carlinville, Macoupin Co., coll. unknown; Havana, Mason Co., G. P. Clinton; Danville, Vermilion Co., coll. unknown.
57. *Stemonitis splendens* Rost. U; BW; Mineral, Bureau Co., A. B. Seymour; Mount Carroll, Carroll Co., H. Shriner; Havana, Mason Co., T. J. Burrill.
58. *Stemonitis virginiensis* Rex. BW; Charleston, Coles Co., H. Ruck.
59. *Comatricha aequalis* Peck. U.
60. *Comatricha cornea* G. Lister and Cran. U; Kickapoo State Park, Vermilion Co.
61. *Comatricha elegans* (Racib.) Lister. U; Wyanet, Bureau Co.
62. *Comatricha fimbriata* G. Lister and Cran. U; Marceilles, La Salle Co.
63. *Comatricha irregularis* Rex. BW.
64. *Comatricha laxa* Rost. U.
65. *Comatricha longa* Peck. U; BW.
66. *Comatricha mirabilis* Benjamin and Poitras. This species, collected on goat dung in moist chamber culture, is known only from type collection. Subsequent to its discovery (Benjamin and Poitras, 1950) it was grown in culture on sterile goat dung, and it produced sporangia identical to those originally encountered. U.
67. *Comatricha nigra* (Pers.) Schroet. U; BW.

68. *Comatricha pulchella* (C. Bab.) Rost. BW; TW; Charleston, Coles Co., H. Ruck.
69. *Comatricha rubens* Lister. TW.
70. *Comatricha typhoides* (Bull.) Rost. U; BW; Canton, Fulton Co., John Wolf; Havana, Mason Co., G. P. Clinton; Kickapoo State Park, Vermilion Co.
71. *Clastoderma debaryanum* Blytt. BW.
72. *Lamproderma arcyrioides* (Sommerf.) Rost. TW.
73. *Lamproderma arcyrionema* Rost. U; BW; Charleston, Coles Co., E. L. Stover; Starved Rock State Park, La Salle Co.
74. *Lamproderma scintillans* (Berk. and Br.) Morgan. U; BW; TW; 2 mi. N.W. Monticello, Piatt Co.
75. *Macbrideola decapillata* H. C. Gilbert. 5 mi. W. Buncomb, Union Co.; Kickapoo State Park, Vermilion Co.
76. *Macbrideola scintillans* H. C. Gilbert. Mount Pleasant, Union Co.

PHYSARALES

Physaraceae

77. *Fuligo cinerea* (Schw.) Morgan. U, T. J. Burrill.
78. *Fuligo intermedia* Macbr. U; Monticello, Piatt Co.
79. *Fuligo septica* (L.) Weber. U; BW; TW; Havana, Mason Co., T. J. Burrill.
80. *Badhamia affinis* Rost. U; TW; 4 mi. S. W. Mason City, Mason Co.
81. *Badhamia capsulifera* (Bull.) Berk. BW.
82. *Badhamia curtisii* (Berk.) Rost. Charleston, Coles Co., E. L. Stover.
83. *Badhamia foliicola* Lister. U; 1 mi. E. Grantsburg, Johnson Co.
84. *Badhamia gracilis* (Macbr.) Macbr. BW.
85. *Badhamia utricularis* (Bull.) Berk. U; TW.
86. *Physarum aeneum* (Lister) R. E. Fries. Starved Rock State Park, La Salle Co.
87. *Physarum auriscalpium* Cooke. U.
88. *Physarum bivalve* Pers. U; BW; 3 mi. S.W. Buncomb, Johnson Co.; Starved Rock State Park, La Salle Co.
89. *Physarum cinereum* (Batsch) Pers. U; Chicago, Cook Co., E. S. Bastin; Starved Rock State Park, La Salle Co.
90. *Physarum compressum* Alb. and Schw. U, W. Snow.
91. *Physarum contextum* (Pers.) Pers. U; BW; TW.
92. *Physarum didermoides* (Pers.) Rost. U; BW; TW; Apple River Canyon State Park, Jo Daviess Co.
93. *Physarum globuliferum* (Bull.) Pers. U; TW.
94. *Physarum gyrosum* Rost. U.
95. *Physarum lateritium* (Berk. and Rav.) Morgan. TW.
96. *Physarum leucophaeum* Fries. U.
97. *Physarum leucopus* Link. U.
98. *Physarum melleum* (Berk. and Br.) Massee. U; BW.
99. *Physarum notabile* Macbr. U; BW; TW.
100. *Physarum nutans* Pers. U; BW; Canton, Fulton Co., John Wolf; Starved Rock State Park, La Salle Co.
101. *Physarum nucleatum* Rex. U; BW.
102. *Physarum oblatum* Macbr. U.
103. *Physarum penetrale* Rex. BW; TW.
104. *Physarum pulcherrimum* Berk. and Rav. BW.
105. *Physarum pulcherripes* Peck. BW.
106. *Physarum stellatum* (Massee) Martin. BW; TW; Starved Rock State Park, La Salle Co.
107. *Physarum polycephalum* Schw. U; BW.
108. *Physarum pusillum* (Berk. and Curt.) G. Lister. 4 mi. E. Urbana, Champaign Co.
109. *Physarum tenerum* Rex. BW.
110. *Physarum virescens* Ditmar. BW.
111. *Physarum viride* (Bull.) Pers. U; BW; 1 mi. S. Gale, Alexander Co.; Starved Rock State Park, La Salle Co.
112. *Craterium aureum* (Schum.) Rost. BW; TW.
113. *Craterium leucocephalum* (Pers.) Ditmar. BW; Charleston, Coles Co., E. L. Stover; Starved Rock State Park, La Salle Co.
114. *Craterium minutum* (Leers) Fries. Charleston, Coles Co., E. L. Stover.
115. *Physarella oblonga* (Berk. and Curt.) Morgan. U; BW; 1 mi. S. Gale, Alexander Co.; 1 mi. E. Grantsburg, Johnson Co.; Kickapoo State Park, Vermilion Co.
116. *Cienkowskia reticulata* (Alb. and Schw.) Rost. U; BW.
117. *Leocarpus fragilis* (Dicks.) Rost. U; Canton, Fulton Co., John Wolf.

Didymiaceae

118. *Diderma effusum* (Schw.) Morgan. BW; TW; 1 mi. E. Grantsburg, Johnson Co.; Kickapoo State Park, Vermilion Co.
119. *Diderma floriforme* (Bull.) Pers. BW.
120. *Diderma globosum* Pers. BW; TW; Apple River Canyon State Park, Jo Daviess Co.
121. *Diderma hemisphaericum* (Bull.) Hornem. 4 mi. E. Urbana, Champaign Co.; BW.
122. *Diderma rugosum* (Rex) Macbr. BW.
123. *Diderma spumarioides* (Fries) Fries. BW.
124. *Diderma testaceum* (Schrad.) Pers. BW; TW; Kickapoo State Park, Vermilion Co.
125. *Mucilago spongiosa* (Leysser) Morgan. U; Apple River Canyon State Park, Jo Daviess Co.
126. *Didymium anellus* Morgan. U.
127. *Didymium clavus* (Alb. and Schw.) Rab. U; BW.
128. *Didymium dubium* Rost. U.
129. *Didymium iridis* (Ditmar) Fries. BW; TW.
130. *Didymium melanospermum* (Pers.) Macbr. U.
131. *Didymium minus* (Lister) Morgan. U; BW; TW; Canton, Fulton Co., John Wolf; 5 mi. W. Buncomb, Johnson Co.; Fort Massac State Park, Massac Co.; 2 mi. N.W. Monticello, Piatt Co.
132. *Didymium nigripes* (Link) Fries. Fort Massac State Park, Massac Co.
133. *Didymium squamulosum* (Alb. and Schw.) Fries. U; BW; TW; Chandlerville, Cass Co., A. B. Seymour; 5 mi. W. Buncomb, Johnson Co.; Starved Rock State Park, La Salle Co.; Danville, Vermilion Co., coll. unknown.

Summary

A check-list of 133 species belonging to 35 genera of Myxomycetes collected in Illinois is given. This collection, which represents 43% of all species and all but 9 genera of Myxomycetes known to occur in North America, is on deposit in the Department of Botany Herbarium, University of Illinois, Urbana.

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CHEMISTRY

POLAROGRAPHY OF SULFHYDRYL-DISULFIDE SYSTEMS

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The polarograph has been applied with success to the determination of cysteine, cystine or thioglycolic acid by Brdička (1933a, b). By this method, the sulfhydryl and disulfide contents of protein hydrolysates were also ascertained and these agreed with values obtained by other procedures (Brdička, 1934, 1938). Although it was not possible to distinguish between sulfhydryl and disulfide catalytic waves, Brdička resolved this problem by the use of potassium iodoacetate. The latter, upon reaction with an aliquot sample of protein hydrolysate over a period of one hour, did not affect the disulfide content but abolished the sulfhydryl contribution to the total wave, according to the following:

$$RSH + ICH_2COOH \rightarrow RSCH_2COOH + HI$$

In the present work, the polarographic determination of the sulfhydryl and disulfide contents of thioglycolate - dithioglycolate mixtures was attempted in the light of the satisfactory results with protein hydrolysates. The study also included a comparison of the sulfhydryl catalytic waves of α- and β-mercaptopropionic acids.

EXPERIMENTAL

Thioglycolic acid was twice distilled under vacuum just prior to use (b.p. 105-108° C. at 20 mm.; collected in water). Dithioglycolic acid, after two recrystallizations from water, melted at 107-108° C. The rectified α-mercaptopropionic acid boiled at 91-93° C. (10 mm.) while the β-mercaptopropionic acid melted at 18.6° C. Cysteine hydrochloride and cystine, both of high purity, originated from Nutritional Biochemicals Corporation. In all instances, mixtures of thioglycolic and dithioglycolic acids were freshly prepared.

Waves were recorded with a Sargent Model XXI polarograph at 25° ± 2° C. The rate of mercury flow at pH 8.45 was 3.23 mg./sec. with a capillary-drop time of 2.65 seconds. Correction of $E_{1/2}$ readings of the cell to S.C.E. was made with a Beckman Model G pH meter employing a platinum anode.

Except for some modifications, the procedure of Brdička was employed. Determinations were carried out in 0.1 N NH_3 - 0.1 N NH_4Cl solution, previously freed of oxygen by bubbling nitrogen through the cell for a period of ten minutes prior to the addition of cobaltous chloride (final concentration = 0.002 N).

The aqueous solution containing sulfhydryl, disulfide or a mixture of these in amounts of 0.01 - 0.001 N was diluted as follows as based on

TABLE 1.—Polarographic Data with Thioglycolate and Dithioglycolate.

Composition in cell, eq. x 10^6		
Sulfhydryl + disulfide	Disulfide	Sulfhydryl determined, eq. x 10^6/1./μa.
8.72[1]	0.0	0.66
8.40[1]	2.58[2]	0.64
8.57[1]	5.48[2]	0.56
8.50	2.09[2]	0.58
31.1	0.0	0.86

[1] K^+ concentration = 0.2 N.
[2] Reaction in presence of iodoacetate proceeded with complete exclusion of catalytic wave.

a total volume of 2.06 ml.: 1) 0.10 ml. test solution, 0.50 ml. 1 N KOH and 1.46 ml. water; and 2) 0.10 ml. test mixture, 0.66 ml. 1 N KOH and 1.30 ml. 0.1 N iodoacetic acid. The latter solution, which contained additional KOH in amount required for the formation of the iodoacetate, was allowed to stand for a period of 1-2 hrs. at 25° C. Both mixtures were then diluted in the following manner upon introduction into the cell: 0.10 ml. Solution (1) or (2), 9.80 ml. 0.1 N NH_3 - 0.1 N NH_4Cl and 0.10 ml. 0.2 N cobaltous chloride.

In several experiments, the potassium ion concentration and pH were varied so as to study their effect on the sensitivity and reproducibility of the catalytic waves, as well as to ascertain the conditions wherein iodoacetate reacts solely with thioglycolate. Alteration of the pH of the ammonia solutions was affected by the addition of concentrated hydrochloric acid.

RESULTS

Representative polarographic data for thioglycolate, dithioglycolate and mixtures of these are presented in Table 1. The effect of varying pH is shown in Table 2 which also includes results with α-and β-mercaptopropionic acids, cystine, and cysteine.

DISCUSSION

It will be observed that catalytic waves for thioglycolate, dithioglycolate or their mixtures were well-defined in the pH range of 2.1 - 9.4. As would be expected, the disulfide yielded twice the wave increment on a molar basis as that obtained with thioglycolic acid. The reaction of iodoacetate with the sulfhydryl-derivative was complete at a pH of 7.5 or higher but only partial at pH 6.7. The wave was poorly defined in buffered solutions of pH greater than 9.5. The present method failed in the analysis of sulfhydryl and disulfide mixtures since reaction with iodoacetate was also noted in the presence of dithioglycolate to the total elimination of the wave. This could not be obviated by variations in potassium ion concentration or pH.

The procedure was checked by repetition of Brdička's experiments

TABLE 2.—Effect of pH on the Catalytic Waves of Thioglycolate-Dithioglycolate Solutions; Results with Meracaptopropionic Acids, Cysteine and Cystine.

Experiment	Composition in Cell, eq. x 10^6		pH	Sulfhydryl determined, eq. x 10^6/1./μa.
	Sulfhydryl	Disulfide		
Thioglycolic acid (II-18).....	65.5	....	6.1	7.55
Thioglycolic acid + iodoacetate (II-18A).....	65.5	....	6.7[1]	22.2
Thioglycolic acid (II-5).....	193.0	....	7.5	0.99
Dithioglycolic acid (II-10)....	.....	50.9	7.15	2.54
Dithioglycolic acid (I-12).....	.....	6.3	9.8[2]	....
Dithioglycolic acid (I-13).....	.....	60.0	8.15	1.54
α-Mercaptopropionic acid (II-15)	127.2	....	8.2	3.72
β-Mercaptopropionic acid (II-4).....	91.6	....	8.6	55.9
Cysteine (II-7).....	36.7	....	7.65	0.85
Cystine (II-8).....	....	42.6[3]	8.45	1.20

[1] At this pH, only part of iodoacetate reacted.
[2] Catalytic wave was poorly defined at this pH.
[3] Disulfide determined: 38.4 x 10^{-6} eq.

with the amino acids, cystine and cysteine; only the latter reacted with iodoacetate and in good agreement with theory. A definite difference is thus apparent between the cysteine-cystine and thioglycolate-dithioglycolate systems. This variation in behavior undoubtedly resides in the dipolar nature of the amino acids and in the differences in stability of the disulfides in basic solution. The half-wave potentials were found to be —1.70 volt vs. S.C.E. at pH 8.2 for thioglycolate-dithioglycolate and —1.58 volt for cystine-cysteine.

A comparison of the catalytic waves obtained with the mercaptopropionic acids indicated a greater wave height for the α-isomer (Table 2).

SUMMARY

Although the total sulfhydryl and disulfide content of thioglycolate-dithioglycolate solutions can be determined polarographically, the individual components of such mixtures did not lend themselves to analysis by these criteria and with the aid of iodoacetic acid. In direct contrast, however, determinations could be carried out with cystine and cysteine, corroborating earlier published findings. The height of the catalytic wave obtained with α-mercaptopropionic acid exceeded that of the β-derivative.

ACKNOWLEDGMENT

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SOME PROBLEMS IN THE SYNTHESIS OF AN ANTIMALARIAL INTERMEDIATE

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Introduction

Intensive research carried out in this country during World War II and the years following showed the marked antimalarial activity of 4-amino-7-chloroquinoline derivatives. The ready preparation of these compounds from 4,7-dichloroquinoline led to much investigation of new procedures for the synthesis of this intermediate. Several preparations have been developed but a shorter, more economical method remains desirable. Although the purpose of this investigation was to develop a new method of synthesizing 4,7-dichloroquinoline, a large part of the work has been concerned with the preparation of intermediate compounds and derivatives of 4,7-dichloroquinaldine. Some of these are new.

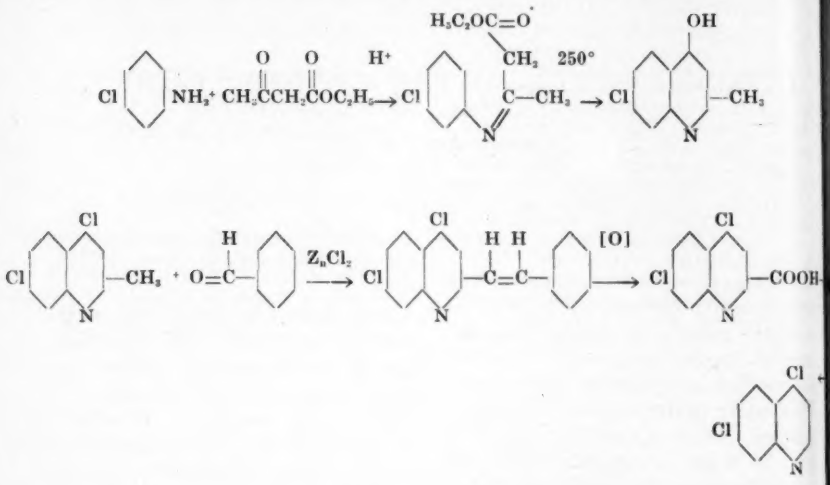
Since, in previous syntheses, one of the principal disadvantages had been the formation of a mixture of isomers in the step involving ring closure, a likely road to the compound seemed to lie in Price, Leonard and Reitsema's (1946:1256) method of condensation of *m*-chloroaniline with acetoacetic ester in the presence of a few drops of concentrated hydrochloric acid as catalyst followed by ring closure in boiling Dowtherm A. Although there is a possibility of the formation of the 5- and 7- isomers in this reaction, only the 7- is formed and this is 70% yield.

After replacing the 4-OH by means refluxing with phosphorus oxychloride in the manner of Ainley and King (1938:73), there seemed to be three possible routes to 4, 7-dichloroquinoline from 4, 7-dichloroquinaldine: 1) direct oxidation to convert the methyl group to -COOH followed by decarboxylation; 2) condensation with an aldehyde to form an unsaturated compound with subsequent oxidation to the acid and decarboxylation; and 3) halogenation of the methyl group followed by hydrolysis and decarboxylation.

Result of the Study

Direct oxidation of 4, 7-dichloroquinaldine using potassium permanganate in hot pyridine according to the manner of Ainley and King (1938:72) produced no apparent effect on the compound.

Condensation with benzaldehyde using the essential method of Rabe (1931:2487), heating in an open flask in the presence of zinc chloride at a temperature of 105°, for 7.5 hours resulted in average 62% yields of the 2-styryl compound (m.p.126°). This, when oxidized by potassium permanganate in cold acetone formed 4,7-dichloroquinaldic

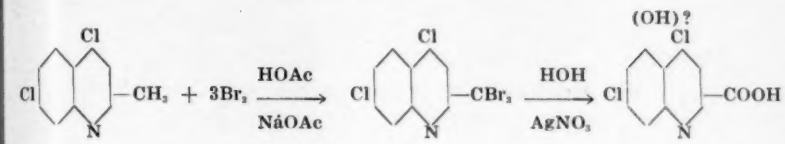


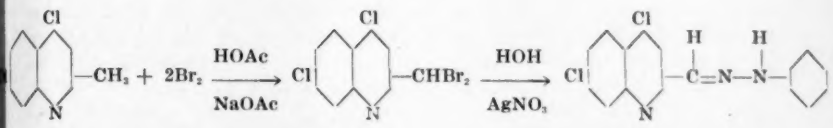
acid (m.p.183°) which, upon decarboxylation in boiling Dowtherm A according to the method of Surrey (1946:113), produced quantitative yields of 4, 7-dichloroquinoline (m.p. 83-84°).

However, since a more economical method was sought and benzaldehyde is expensive, similar condensations were tried with formaldehyde and acetaldehyde. The former resulted in polymerization and the latter in no identifiable product but considerable amounts of the starting materials.

Bromination of the 4, 7-dichloroquinaldine in the presence of benzoyl peroxide, phosphorus oxychloride or ultra violet light, all resulted in very good yields of the ∂-tribromo-derivative of 4, 7-dichloroquinaldine. The method of Hammick (1923:2882) was used. In a three-necked, round-bottom flask, fitted with a condenser, calcium chloride tube, mechanical stirrer and dropping funnel, were placed 27.5 ml. of glacial acetic acid, 11.8 gms. of anhydrous sodium acetate, and 5 gms. of 4, 7-dichloroquinaldine. The mixture was heated in a water bath at 70-75°, and 3.7 ml. of bromine in 18 ml. of glacial acetic acid were added from the dropping funnel during 20 minutes. The temperature of the bath was raised to 90-95° and heating was continued for one hour. The reaction mixture was allowed to stand overnight and then was filtered. The white solid so obtained was triturated with 200 ml. of water, the mixture filtered, and the solid collected and dried. The product weighed 9.5 gms. (m.p. 110-116°). This represents an 89% yield. Two recrystallizations from 95% ethyl alcohol raised the melting point to 143°. (Analysis: $C_{10}H_4N Cl_2Br_3$: Calculated: C 26.7, H 0.89, N 3.12. Found: C 25.76, H 0.87, N 3.29).

Hydrolysis by means of refluxing for four hours with silver nitrate as suggested by Krahler and Burger (1942) resulted in low yields of an





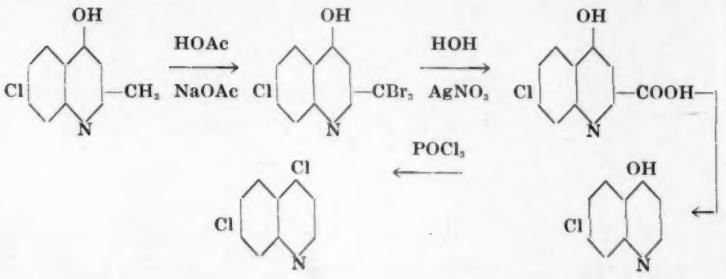
acid with carbon, hydrogen and nitrogen content very close to that of 4, 7-dichloroquinaldic acid. (Analysis: $C_{10}H_5O_2N\ Cl_2$: Calculated: C 49.6, H 2.08, N 5.70. Found: C 49.1, H 2.30, N 6.00). However, the melting point (245-248°) is much closer to that of 4-OH-7-Cl-quinaldic acid (m.p. 277°).

This posed the question as to whether or not the 4-Cl had been removed by the silver nitrate hydrolysis. Decarboxylation of the acid produced a small amount of white solid (m.p. 278°) which corresponds to the melting point of 4-0H-7-Cl-quinoline (m.p. 277-279°) and also indicates that the 4-Cl has probably been removed.

As a further test to determine the position of the bromine and to see whether or not the 4-Cl had retained its position, the dibromo product (m.p. 190°) was prepared in the same manner as the tribromo derivative. (Analysis: $C_{10}H_5N\ Cl_2Br_2$: Calculated: C 32.46, H 1.36, N 3.78. Found: C 32.82, H 1.33, N 3.90). Silver nitrate hydrolysis of the dibromo derivative led to the formation of low yields of 4, 7-dichloroquinaldehyde (m.p. 153-155°) which was converted directly to the corresponding phenylhydrazone (m.p. 210-213°) according to the method of Shriner and Fuson (1948:68). (Analysis: $C_{16}H_{11}N_3Cl_2$: Calculated: C 60.77, H 3.50, N 13.29. Found: C 60.60, H 3.60, N 13.20). Further work is being done to increase the yields and to determine the exact nature of the hydrolysis products.

Because the 4-Cl seems to be affected by the silver nitrate and because the 4-chloro compounds are quite soluble and difficult to isolate, a similar investigation is being carried out to effect the same reactions on the 4-OH-7-Cl-quinaldine. These compounds are more stable and much less soluble than the corresponding 4-Cl compounds.

Quantitative yields of the tribromo derivative of 4-OH-7-Cl-quinaldine (m.p. 326°) have been produced. Attempts are being made to hydrolyze the bromination product to determine the difference between the effect of the 4-OH and the 4-Cl. Should the hydrolysis of the tribromo derivative of the 4-OH compound prove to be more readily accomplished, the replacement of the 4-OH by -Cl could easily be effected by the action of phosphorus oxychloride on the decarboxylation product.



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REACTION OF ETHYLENE OXIDE WITH ANTIMONY CHLORIDES

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The reaction of ethylene oxide with several inorganic halides is described in the literature. For example, arsenic trichloride at room temperature yields β-chloroethyl ethers of arsenic chlorides (*e.g.* $Cl\text{-}CH_2\text{-}CH_2\text{-}O\text{-}AsCl_2$) (Malinovskii, 1940) while boron trifluoride, silicon tetrafluoride, and arsenic trifluoride transform ethylene oxide into dioxane (Schmeisser and Jenkner, 1952) Sulfur dichloride and ethylene oxide react with the formation of ethylene dichloride and ethylene chlorohydrin as well as β-chloroethoxy sulfoxide (Malinovskii, 1939).

Similar experiments were carried out in this laboratory with the chlorides of antimony.

Materials and Method

The reaction vessel consisted of a 500-ml., three-necked flask, fitted with a gas dispersion outlet leading to the bottom of the flask, a thermometer and a delivery tube. The delivery tube was provided with a Claissen distilling head, fitted with a thermometer and connected to a water condenser and receiving flask in order to isolate the distillate. An oil trap was attached to the end of the system to provide a slight pressure. Ethylene oxide gas was passed into the dispersing tube along with an alternate feed of nitrogen; the latter was used to displace air and moisture from the system. The reaction vessel was heated with a rheostat-controlled glas-col mantle.

In a typical experiment, the reaction vessel was charged with catalyst which was preheated to 75-100° C. in the inert nitrogen gas. Ethylene oxide gas was then passed through the catalyst so that only a few bubbles escaped through the oil trap. The temperature quickly rose to 180-200° C. and was maintained in that range by the heating mantle as well as by the heat of the reaction. As the reaction progressed the volatile products distilled from 80-130° C. and after 6-8 hours the system was purged with nitrogen to displace the remainder of the volatile materials. The distillate was then fractionated in a heated, 18-inch column, packed with glass helices, and the fractions were identified from their physical properties. The proportion of each product was estimated from the distillation curves.

Results

Antimony pentachloride.—When 250 gms. (0.86 moles) of antimony pentachloride was treated with 250 gms. (5.68 moles) of ethylene oxide, over a period of 7 hours, the evolution of hydrogen chloride gas was noted. The volatile distillate (B.P. 80-130° C.) amounted to 160 ml. along with 10 gms. of sublimed, white crystalline solid. The solid was identified as antimony oxychloride by melting point (170° C.) as well as by antimony (70.14%) and

TABLE 1.—Yields and Physical Constants of Distillate from the Reaction of Ethylene Oxide and Antimony Chlorides.

	Ethylene dichloride	Dioxane	Ethylene chlorohydrin
From antimony pentachloride			
Percent yield*	2.2	23.2	12.9
B.P.° C.	80-83	101-102	127-128
N_D^{20}	1.4440	1.4223	1.4423
D_4^{20}	1.2445	1.0305	1.1957
From antimony trichloride			
Percent yield*	8.0	38.3	13.1
B.P.	80-82	101-102	127-129
N_D^{20}	1.4450	1.4213	1.4415
D_4^{20}	1.2535	1.0321	1.1970
Literature values (Heilbron, 1953:502, 398, 501)			
B.P.	83.7	101	128.6
N_D^{20}	1.4443	1.4224	1.4419
D_4^{20}	1.2521	1.0337	1.1988

*Yields based on ethylene oxide used.

chlorine (21.23%) analyses. Theoretical values for SbOCl are 70.29% Sb and 20.47% Cl.

The black tarry residue remaining in the reaction vessel weighed 197 gms. and contained 45.3% antimony and 38.5% chlorine. This corresponds to 89% of the original antimony content of the catalyst. Aside from a small quantity of SbOCl in the residue, attempts to isolate pure compounds proved futile, although the above analyses do correspond to $Cl\text{-}CH_2CH_2\text{-}O\text{-}SbCl_4$ (Sb, 44.7%; Cl, 39.1%).

The volatile liquid from the reaction was then distilled and dioxane, ethylene dichloride, and ethylene chlorohydrin were identified as the chief components. The yields and physical constants used to identify the products are listed in Table 1.

Antimony trichloride.—Two hundred gms. (0.915 moles) of antimony trichloride were treated with 250 gms. (5.68 moles) of ethylene oxide over a period of 8 hours. The reaction did not appear to be as vigorous as with the pentachloride and no evolution of hydrogen choloride was noticed. In addition, no antimony oxychloride sublimed with the distillate. In this experiment, 195 ml. of distillate boiling from 80-130° C. was obtained along with the black residue remaining in the flask. Ethylene dichloride, dioxane, and ethylene chlorohydrin were likewise identified as the chief products of the condensation. The yields and

physical constants of these products are also listed in Table 1.

The black residue (235 gms.) contained 39.1% antimony and 32.3% chlorine, corresponding to $(Cl\text{-}CH_2CH_2\text{-}O)_2\text{-}SbCl$ (Sb, 38.5%; Cl, 33.7%). Vacuum sublimation did not produce any antimony oxychloride and only traces of antimony trichloride from this residue. Purification was unsuccessful.

Discussion and Summary

The reaction of antimony pentachloride with ethylene oxide produced hydrogen chloride, antimony oxychloride, dioxane, ethylene dichloride, and ethylene chlorohydrin. These products indicate that the pentachloride quite possibly decomposes part of the ethylene oxide to oxygen or water, and hydrogen chloride is formed by chlorination of the ethylene oxide. The oxygen or water converts the antimony chloride to the oxychloride. Ethylene chlorohydrin, which may also be converted to the dichloride with hydrogen chloride, is formed from ethylene oxide and hydrogen chloride or by hydrollysis of the chloroethers of antimony chlorides. Dehydrohalogenation of ethylene chlorohydrin would account for the dioxane. The analyses on the organic residue correspond to the β-chloroethyl ether of antimony chloride.

The probable reactions may be represented as follows:

$$CH_2\text{-}CH_2\text{-}O + SbCl_5 \longrightarrow Cl\text{-}CH_2\text{-}CH_2\text{-}O\text{-}SbCl_2$$

$$Cl\text{-}CH_2\text{-}CH_2\text{-}O\text{-}SbCl_2 + H_2O \longrightarrow HO\text{-}CH_2\text{-}CH_2\text{-}Cl + SbOCl \text{ (trace)} + HCl$$

$$CH_2\text{-}CH_2\text{-}O + HCl \longrightarrow HO\text{-}CH_2\text{-}CH_2\text{-}Cl$$

$$2HO\text{-}CH_2\text{-}CH_2\text{-}Cl \longrightarrow O\text{-}CH_2\text{-}CH_2\text{-}O\text{-}CH_2\text{-}CH_2 + 2HCl$$

$$HO\text{-}CH_2\text{-}CH_2\text{-}Cl + HCl \longrightarrow Cl\text{-}CH_2\text{-}CH_2\text{-}Cl$$

Since the reaction with antimony trichloride does not produce noticeable quantities of hydrogen chloride, the ethylene chlorohydrin is more probably formed by hydrolysis of chloroethylethers of antimony chlorides. This is further indicated by the higher overall yields of the distilled products from the latter reaction and, therefore, less decomposition of the ethylene oxide. In the latter instance the analyses on the residue indicate the formation of $(Cl\text{-}CH_2\text{-}CH_2\text{-}O)_2\text{-}SbCl$.

The reaction of ethylene oxide and antimony chlorides produces dioxane, ethylene chlorohydrin, and ethylene dichloride, as well as hydrogen chloride. With antimony pentachloride a small amount of antimony oxychloride was isolated. The antimony residues apparently contained organic matter, and analyses on the crude material correspond to β-chloroethyl ethers of antimony chloride. However, no purified organic antimony compounds were isolated.

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THE POLAROGRAPHIC DETERMINATION OF SULFHYDRYL GROUPS

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A number of electrometric methods for determination of sulfhydryl (SH) groups have been evolved. Examples of these methods include: polarographic measurement of the SH anodic wave (Kolthoff and Barnum, 1940); amperometric titration with the rotated platinum electrode (Kolthoff, *et al.*, 1954); and measurement of the catalytic evolution of hydrogen produced by SH groups at the dropping mercury cathode (Heyrovsky and Babicka, 1930; Birdicka, 1933). The fact that p-chlormercuribenzoate is a highly specific reagent for mercaptide formation with SH groups and that Benesch and Benesch (1953) demonstrated that SH groups produce a diminution of the first polarographic reduction wave height of phenylmercuric hydroxide has focussed attention on the possible utility of p-chloromercuribenzoate (PCMB) as a reagent for polarographic determination of SH groups in amino acids, proteins, and enzyme homogenates. It was reasoned that any diminution of the first wave of the PCMB might be attributable to quantitative production of a mercaptide (from the SH compound and the PCMB) which would be more resistant to polarographic reduction (*i.e.*, reduced at a more negative potential) than the PCMB. Test of this proposition has been undertaken in the work reported here. Use of the method which has resulted from this work in connection with drug action mechanism studies will be discussed.

Materials

Amino acids and peptides used included cysteine hydrochloride, glycine, cystine, and reduced glutathione. All of these were products of Eastman Kodak Co. Stock solutions of cysteine hydrochloride, glycine, and glutathione were prepared at 10^{-3} M concentration in air-free water freshly distilled from a pyrex still. Stock solution of the cystine consisted of 10^{-3} M cystine in 0.1N sodium hydroxide made up with pyrex glass distilled water. Fresh stock solutions of these substances were prepared each day. Proteins used were crystalline bovine plasma albumin and crystalline zinc insulin, both of which were products of Armour Laboratories. The albumin was found to contain water (6-7%) and was always heated at 110° C. to constant weight before use. The activity of the insulin preparation was 25 units per mg. ± 5%. Parachloromercuribenzoic acid was synthesized according to the method of Whitmore and Woodard (1932). Reagent solutions of the PCMB were 8.4×10^{-4} M and were prepared by adding 3 ml. of 0.1 N potassium hydroxide to 30 mg. of the acid and 20 ml. of distilled water in a 100 ml. volumetric flask, shaking to dissolve the acid, and diluting to the mark

with distilled water. The buffer solution used in the determinations was a M/15 phosphate buffer, pH 7.4, made up according to the method of Hastings and Sendroy (1924: 706). All chemicals used were C. P. reagent products unless otherwise indicated.

A model XXI Sargent recording polarograph was used in all determinations. The capillary used for the dropping mercury electrode had the following characteristics: m = 3.76 mg./second, t= 2.56 seconds/drop at –0.4 V vs. the Hg pool. The mercury pool served as reference electrode. In most cases the current sensitivity used was 0.010 μa/mm.

Methods

Proportionality between PCMB concentration and the first reduction wave of the PCMB was ascertained by adding varying volume increments of the PCMB reagent solution to 5 ml. of the phosphate buffer, effecting final dilution to 10 ml. with distilled water in each case, and polarographing after oxygen had been removed by passing nitrogen through the solutions for 10 minutes. Determinations of the effect of amino acids, peptides, and proteins on the first polarographic reduction wave of the PCMB were carried out by adding aliquots of appropriately diluted stock solutions of these substances to 5 ml. of phosphate buffer and 2 ml. of the PCMB reagent solution, making the volume to 10 ml. with distilled water, and polarographing following deaeration as before. The effect of appropriate aliquots of homogenate solutions was determined in the same manner. The polarographic effect of all biochemical substances tested was compared with a polarogram from a control solution of equal PCMB concentration run at the same time.

Results

The two polarographic waves yielded from the reduction of the PCMB are shown in Figure 1. The first wave has a half-wave potential ($E_{1/2}$) of –0.28 V vs. the Hg pool, while the second wave $E_{1/2}$ occurred at –0.79 V vs. the Hg pool. Figure 2 shows that a straight line relationship exists when the PCMB first wave height is plotted against PCMB concentration under the polarographic conditions used. It was found that cysteine hydrochloride, in the concentrations tried (from 5 μg. to 25 μg./ml.), effected diminution of the first PGMB wave height and that this reduction in wave height was proportional to the cysteine concentration. This relationship is illustrated in Figure 3. Table 1 illustrates typical results obtained from SH determination in amino acids, peptides and proteins. These results indicate that fairly ac-

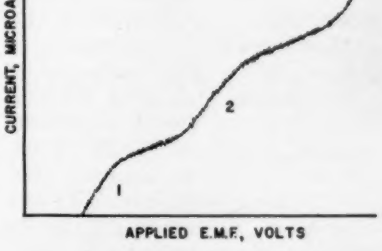

Figure 1

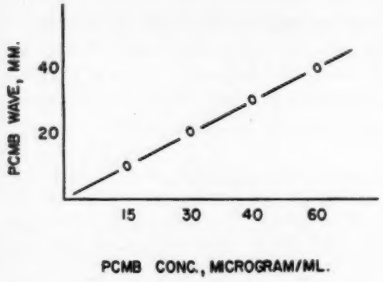

FIGURE 2

curate determination of the SH content of these compounds can be effected using the method and that disulfide compounds (*i.e.*, insulin, cystine) are not likely to interfere with the determination of SH by this procedure. Tissue homogenates of heart and kidney caused diminution of the first PCMB wave that was proportional to the homogenate volume increment added to the PCMB-buffer solution.

DISCUSSION

The results obtained would seem to indicate that the method evolved for SH determination is capable of a wide range of utility. It appears to be applicable to SH determination in large and small molecules with reasonable accuracy at low SH concentrations. The experiments demonstrate that in all probability the method is relatively free from interference due to likely contaminants.

Comparison with other available methods reveals that it is probably superior to indicator titration methods and equal in accuracy and utility to amperometric titration procedures. At its present stage of development the method is more accurate than the method employing use of catalytic evolution of hydrogen measurement (Birdicka, 1933), but it is less versatile than this method which can be used to measure disulfide as well as SH.

Use of the procedure being reported here has already been made in our laboratory in the course of studies of the mechanism of the action of drugs. We have advanced an hypothesis on the mechanism of cardiac glycoside action on the heart, the details of which are in press elsewhere (Proctor, *et al.*, 1955). This hypothesis postulates cardiac glycoside inhibition of heart adenosinetriphosphatase (ATPase) and acetylcholinesterase (AcHase), both of which require free SH groups for activity. Cardiac glycosides have an unsaturated lactone ring (located at C-17 in the steroid moiety of the molecule) which is capable of SH reactivity in two possible ways. Addition of SH to the carbon-carbon double bond can occur and the lactones can form peroxides (Kirkland, *et al.*, 1950) which could in turn oxidize SH to disulfide. Our work to date has demonstrated that digi-

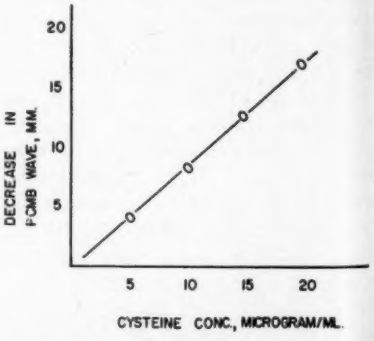

FIGURE 3

TABLE 1.—Sulfhydryl Determination in Various Compounds.

Compound	SH	1st PCMB wave depression	Calculated mole SH/mole compound	
			found by PCMB polarography	theoretical
cystine	absent	—	none	none
glycine	absent	—	none	none
glutathione[1]	present	+	1.02, 1.01, 1.00, 0.98	1.00
albumin[2]	present	+	0.60, 0.65, 0.66, 0.61	0.66
insulin	absent	—	none	none

[1] Reduced form, last two determinations made in the presence of cystine.
[2] Molecular weight assumed to be 70,000.

toxin, at concentrations approximating levels reached *in vivo* in therapeutic dosage, brings about *in vitro* inhibition of the two enzymes in heart muscle of dogs and rabbits. This inhibition is enhanced by effecting glycoside lactone ring peroxide formation (Proctor, *et al.*, 1955). Using homogenates from these experiments it has been ascertained by the PCMB method for SH determination that the inhibition observed correlates qualitatively with the degree of SH "lost" from the homogenate in the presence of the glycoside. While these findings do not definitely establish the SH-digitoxin mechanism postulated by the hypothesis (this must await similar study of digitoxin effect on purified enzymes) the qualitative correlation obtained gives preliminary support to the hypothesis. It is also of interest to note that the digitoxin enzyme inhibitions can be reversed by SH compounds.

SUMMARY

An indirect polarographic method for the determination of sulfhydryl groups in amino acids, peptides, and proteins has been described. Essentially the determination consists of measuring the quantitative depression of the wave height of the first polarographic reduction wave of p-chloromercuribenzoate caused by sulfhydryl compounds.

Accuracy and comparative advantage of the method in relationship to other methods has been discussed.

Application of the method in a pharmacodynamic study has been described.

ACKNOWLEDGMENT

The author gratefully acknowledges the support provided for this work by a grant from the Chicago Heart Association.

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GEOGRAPHY

DIFFERENTIAL POPULATION GROWTH OF INCORPORATED MUNICIPALITIES IN THE CHICAGO SUBURBAN REGION

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Like most metropolitan centers in the United States, Chicago is being surpassed in population growth, both numerically and percentage-wise, by its suburban region. This is not a new trend, however. In terms of rates of increase, it has been true since the turn of the century; in terms of absolute growth, it has been true since 1930.

Studies completed in January, 1956, indicate, moreover, that the city is continuing to gain fewer people and to grow at a slower rate than its suburban region. It is generally agreed that during the past 5 years, the city has grown at a rate of 5.5%. This gives it a population today of about 3,800,000; an increase of 200,000 since 1950. In contrast, it is estimated that its suburban region has gained approximately 446,000 inhabitants since 1950, or at a rate of 28.3%. If continued at this rate for the next five years, the suburban growth for the decade 1950-1960 will match that of the 1920's; the city's rate, however, will have fallen far behind.

Centers of population growth within an area are as significant to the geographer, however, as rates of increase. Problems of education, housing, integration, and transportation are dependent on the area as well as on the rapidity of growth. It is the purpose of this paper, therefore, to present rates of population growth of incorporated municipalities in the Chicago suburban region for the past five years, and to note differences in their growth patterns.

The Area Studied

As outlined on Figure 1, the area included in this study is limited to Lake, Cook, and DuPage counties in northeastern Illinois, to that part of Lake County, Indiana, which lies to the north of Crown Point, and to Crete Township in Will County, Illinois. The area so delimited is hereafter referred to as the Chicago suburban region. It includes the entire urbanized area of Chicago as defined by the Bureau of the Census in 1950, with the exception, of course, of the city itself. It does not include, however, all of the "Standard Metropolitan Area" as defined by the census.

Within this region are 155 incorporated municipalities. Although a number of these had their origins more than 100 years ago, substantial growth has taken place only since 1890. Since then, and especially in the 1920's and the past ten years, a large proportion of these municipalities has experienced rapid growth.

Estimates indicate that in 1955,

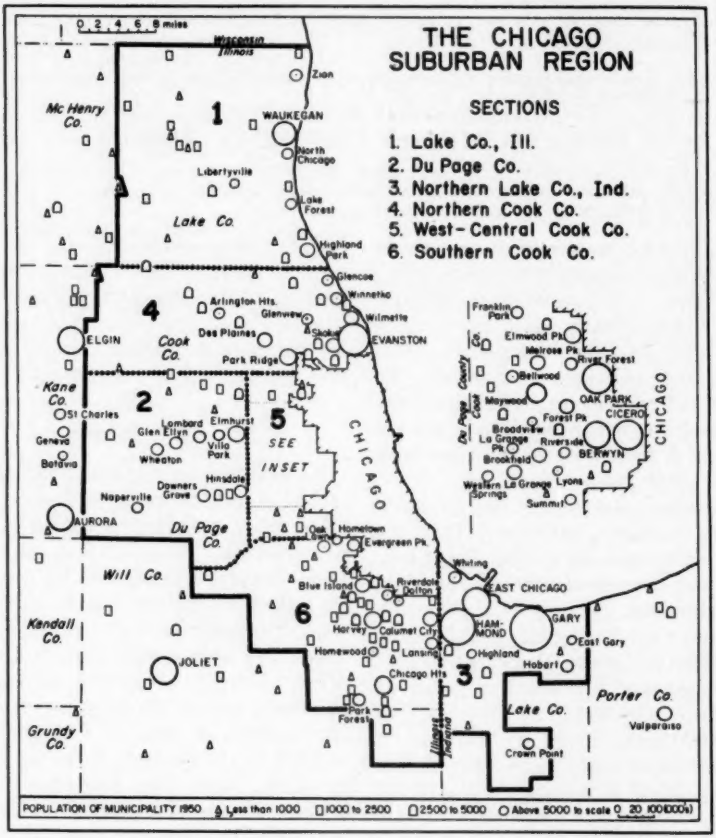

FIG. 1.—Cities named are indicated by dot in center of appropriate circle.

the 155 incorporated municipalities of the Chicago suburban region had a population of nearly 1,750,000. This represents a numerical increase since 1950 of nearly 415,000, or an average percentage growth of 31%. An additional 273,000 live in unincorporated areas. It is estimated that the Chicago suburban region has a total population today of more than 2,000,000, compared to the city's population of 3,800,000. The ratio of population in the city to that of the suburban region is now less than 2 to 1.

BASIS OF ESTIMATES

The population estimates presented in this paper are based on data collected from a number of sources late in 1955. For that year

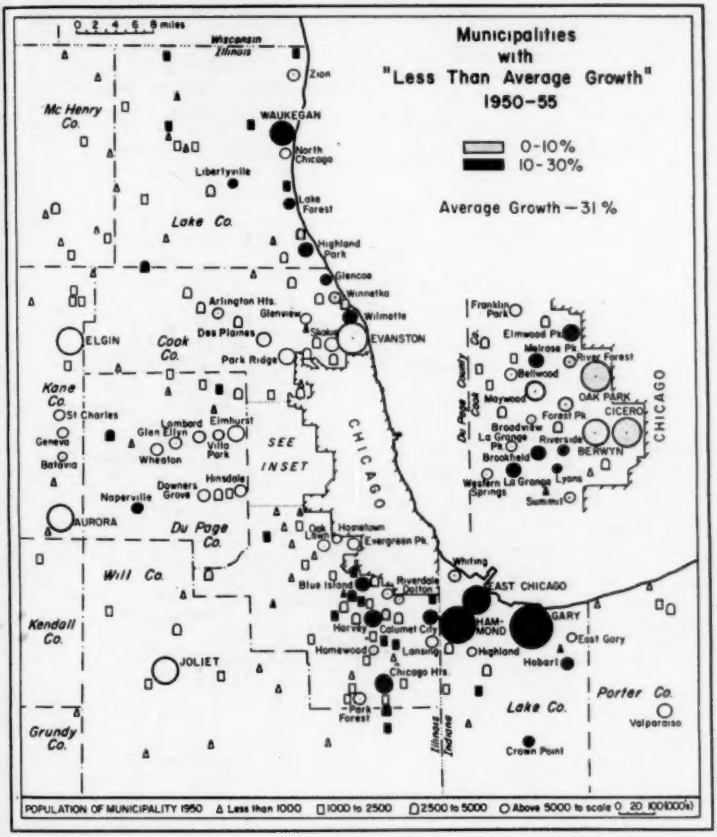

FIGURE 2

supplemental United States Census counts were made for 40 municipalities located within the Chicago suburban region. These data were used, wherever possible, to determine the rate of growth. Estimates of population for those municipalities for which there were no supplemental United States Census counts were based on: 1) field mapping of new dwelling units; 2) comparison of aerial photographs taken in the 1940's and in 1955; 3) examination of records of building permits; 4) forecasts by other groups and organizations; 5) studies of recent birth rates and school populations; and 6) records of family service agencies. Great reliance was placed on correlations which were established between number of residential building permits and population increases. Correlations were established for suburban communities for

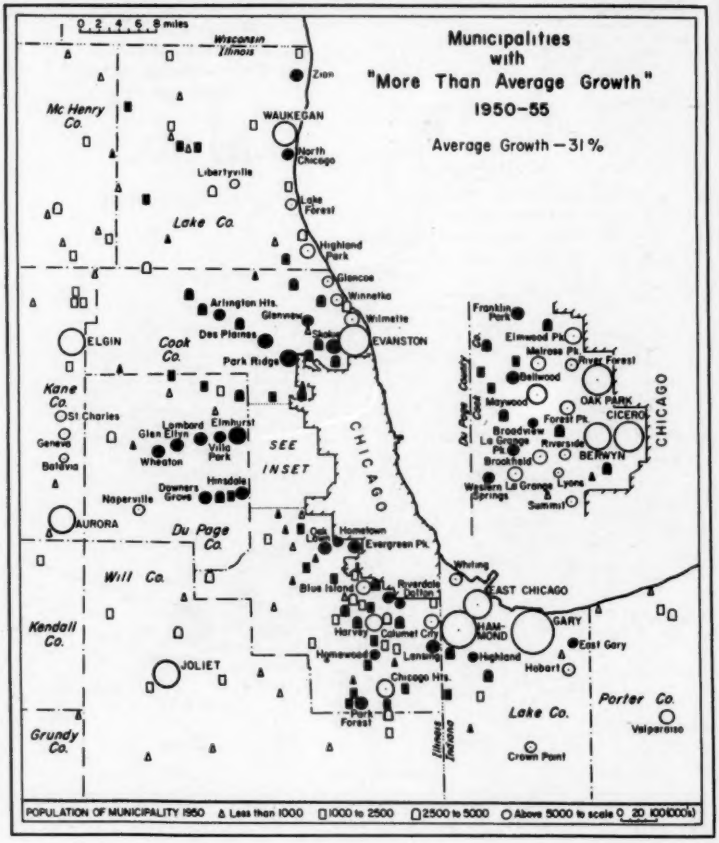

FIGURE 3

which the United States Census Bureau made supplementary census counts in 1955; these were then applied to other communities having similar characteristics.

It was difficult to estimate population growth for the areas of unincorporated land within the region studied. Late census counts have not been made for such areas, and building permits are not recorded on a township basis. As a result, their 1955 population was projected by means of a straight "least-squares" trend line. It should be noted that such projections are likely to err on the conservative side because of the statistical technique employed. This is certainly true for DuPage County where growth in unincorporated areas is certainly much higher than indicated by the statistical technique used.

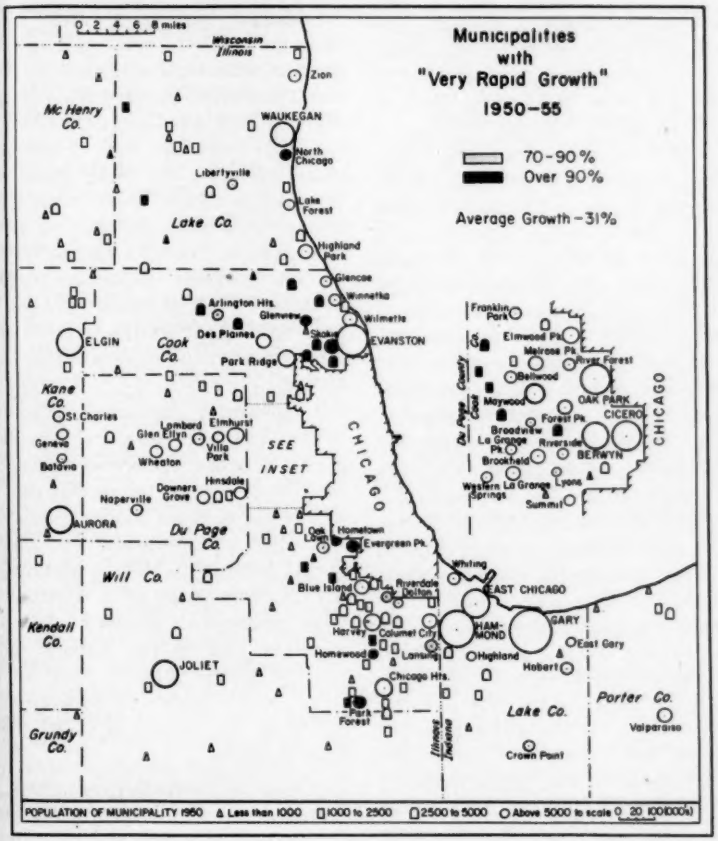

FIGURE 4

ANALYSIS OF DATA

In analyzing the differential population growth of incorporated municipalities in the Chicago suburban region, attention is directed to: 1) population growth by sections; 2) growth of the large municipalities; 3) municipalities of less than average growth; 4) municipalities of more than average growth; and 5) municipalities of very rapid growth.

Population growth by sections.— The several sections of the Chicago suburban region are growing at different rates. Northern Cook County (Fig. 1, Sec. 1) has gained the largest number of people, but ranks second to southern Cook County in rate of increase. West-central Cook County and northern Lake County, Indiana, rank third and fourth, respectively, in terms of numerical increases, but fifth and sixth in terms

of rates of growth. DuPage and Lake counties have gained fewer people than any of the other sections, but rank third and fourth in terms of percentage increases.

Growth of the large municipalities.—In 1950, there were 30 municipalities in the Chicago suburban region which had a population of more than 10,000. Seven exceeded 50,000 and one, Gary, exceeded 100,000. From the standpoint of numbers, growth in these large municipalities has been outstanding. Altogether, the 30 cities account for nearly 41% of the total increase registered for all the suburban municipalities. Two cities, Skokie and Gary, have each gained more than 20,000 residents during the past 5 years.

On a percentage basis, however, the large cities of the Chicago suburban region have not equalled the population growth experienced by some of the smaller municipalities. As a whole, the 30 larger municipalities have gained at a rate of only 18.4%. Only 7 of the 30 have gained at rates faster than the average for all of the suburban municipalities. All of the first 10 have increased at rates lower than the 31% average. Of these, Evanston, Cicero, Oak Park, Berwyn, and Maywood have registered very small rates of increase since 1950.

Municipalities with less than average growth.—The municipalities which have grown at rates lower than the area's average of 31% are indicated in Figure 2. These include: 1) all North Shore municipalities, except North Chicago and Zion; 2) a cluster of municipalities along the west-central limits of Chicago, including the large and long-established centers of Oak Park, Berwyn, and Cicero, and several nearby residential suburbs; 3) four small industrial centers, Blue Island, Harvey, Chicago Heights, and Calumet City, together with a few very small suburbs; 4) large industrial cities of northern Lake County, Indiana; and 5) a number of small communities located near the fringes of the Chicago suburban region, principally in the lake region of western Lake County, western DuPage County, and southwestern Cook County.

In general, it appears that the suburban municipalities which have grown at less than average rates include: 1) older municipalities in which there is no longer room for extensive development of single-family homes; 2) industrial municipalities which may have experienced large numerical increases but because of size do not register high rates of growth; and 3) small settlements which are still considered too far from the central city for daily trips to work.

It may be predicted that rates of growth in the older suburbs will continue to decelerate unless single-family homes are replaced by multiple dwelling units or the suburbs annex additional land. Small settlements now located near the fringes of the Chicago suburban region will grow more rapidly if the present widespread demand for single-family homes, located in the open country, continues. Finally, it may be predicted that present industrial centers will grow at a more rapid rate when strong attractive forces, such as the St. Lawrence Seaway and the deepening of the Sag Chan-

nel, cause industrial location in the Chicago suburban region.

Municipalities with more than average growth.—Eighty-nine municipalities in the study area (Fig. 3) have added more than 31% to their population in the last five years. These include: 1) scattered small settlements in western Lake County in which former resort dwellings are being converted into year-round homes, and new dwellings being built, and from which many workers commute to Waukegan and North Chicago as well as to the city of Chicago itself; 2) a string of municipalities which lie inland from and roughly parallel to the North Shore suburbs, including Skokie (which has achieved the largest numerical increase of any Chicago suburban municipality), Lincolnwood, Niles, Morton Grove, Glenview, Northfield, Northbrook, and Wheeling—all more dependent on the automobile than on rail transportation for commuting; 3) all but five municipalities of DuPage County, comprising three distinct string settlements: in the north along the Chicago, Milwaukee, St. Paul and Pacific Railroad; centrally, along the Chicago and Northwestern Railroad; and in the south along the Chicago, Burlington and Quincy Railroad and Ogden Avenue; and 4) a large number of residential, dormitory suburbs located on or near main railroad lines and major highways in southern Cook County.

Municipalities of extremely rapid growth.—Since 1950, 29 municipalities have more than doubled their populations. (Fig. 4) A third of them are in northern Cook County. They include Skokie, Niles, Northbrook, Lincolnwood, Morton Grove, Wheeling, Northfield, Glenview, Mt. Prospect, and Rolling Meadows which now has an estimated population of more than 5000. It is a dormitory suburb which has been built since 1950.

The second largest area of rapidly growing municipalities lies to the south of Chicago. Here may be found such suburbs as Evergreen Park, Hometown, and Park Forest, all residential developments of recent years.

It is interesting to note that no city in northern Lake County, Indiana, or in DuPage County, Illinois, has doubled its population since 1950. All of the cities in these counties have grown at more than average rates, but not so phenomenally as have the suburbs in northern and southern Cook County.

Future Trends

Based on field observations and the trends of the time, it is predicted that the population of the Chicago suburban region will continue to increase at about the same rate as it has since 1950. An expected additional increase of some 440,000 is indicated. This will bring the total 1960 population to nearly 2,460,000. The average rate of growth for the Chicago suburban region over the ten-year period will amount, therefore, to nearly 56%.

Again, based on empirical evidence, it is expected that the higher rates of increase during the next five years will take place in DuPage County and in southern Cook County. Northern Cook County will continue to gain numerically but at a lower rate.

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THE URBANIZATION OF ILLINOIS: 1870-1950

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Illinois has more than three-quarters of its population in towns and cities. The state's degree of urbanization has thus greatly increased from the 24% recorded in 1870, the first usable, detailed census. (All data in this paper are calculated from U.S. Census reports for 1870, 1900, and 1950.) Nevertheless, there has been little movement of the center of urban population during the past 80 years. There have, however, been striking changes in the detailed patterns of urbanization of Illinois since 1870. There have been variations in the percentage importance of urban population within counties, in the share of the state's total urban population of the various counties, and in the timing of major changes in the degree of urbanization of counties. These changes are significant in the development of the present pattern of urbanization in Illinois, one of the highly urbanized states of the nation.

People living in urban areas (incorporated settlements of at least 2,500 persons) were a significant part of the total population in only a few Illinois counties in 1870 (Fig. 1). Only six counties, mostly in the northern one-half of the state, were more than 40% urbanized. Five of these six (Cook, Rock Island, Peoria, Adams, and Alexander; see Fig. 9 for county names) each contained one primary urban center—centers in which a transportation function was dominant. In Chicago (Cook Co.) railroads were replacing water as the principal transportation medium; in the other four primary centers river traffic still was dominant. Kane County, the sixth one more than 40% urbanized, contained the old Fox River Valley settlements, none of which was clearly dominant and none of which was primarily a transportation center. The southern one-third of the state was practically devoid of counties significantly urbanized—a fact partly responsible for the northern position of the 1870 center of urban population. The majority of all urbanized counties, including most of those very highly urbanized and containing major transportation centers, was located in the northern one-half of the state. Nevertheless, no particular pattern or uniformity of urbanism had as yet emerged in 1870.

In 1900 (Fig. 2) six counties were again prominent as especially highly urbanized (now measured by at least 60% urban population). Five of the six noted for 1870 were still leaders; the one change in the group had been the substitution of Winnebago County (Rockford) for Adams County (Quincy). Five of the six were again dominated by one center (Kane was still the exception), but the primary cities had now become manufacturing centers. The substitution of Winnebago for Adams

County emphasized the decline of water transportation as a primary factor in urban growth in the state. Cairo (Alexander Co.) was the only one of the larger cities which was still primarily dependent upon transportation activities, and Alexander had the smallest net increase in urban population of these six counties. Chicago, on the other hand, had been the most successful manufacturing center of the state, and between 1870 and 1900 Cook County registered the highest net increase in urban population. By 1900, urbanism had increased throughout the state as a whole. By the same date, a group of secondary urban counties had developed to a level (40-59% urban) which would have put them in first rank only 30 years previously. These latter counties were primarily in the center and north of the state and the southeast quadrant was not significantly urbanized even by 1900.

Only two groups of Illinois counties remained completely non-urban as late as 1950—a tier along the Wabash-Ohio rivers and a cluster along the Middle Illinois River (Fig. 3). A third group (five counties) along the Lower Illinois-Mississippi rivers showed little or no urban population. The other exceptions were scattered. By 1950, the population of 16 of the 102 counties was 60% or more urban. All 7 of the highly urbanized counties recognized in 1870 and 1900 were in the group. Of the 16 highly urbanized counties in 1950, all but 3 had 40% or more of their population urban in 1900. (The three exceptions were DuPage and Madison, part of the metropolitan area growth of Chicago and East St. Louis districts, and Champaign, where different census techniques were responsible for an apparent change.) Only 3 counties which had been 40% or more urban in 1900 (Boone, Morgan and Will) failed

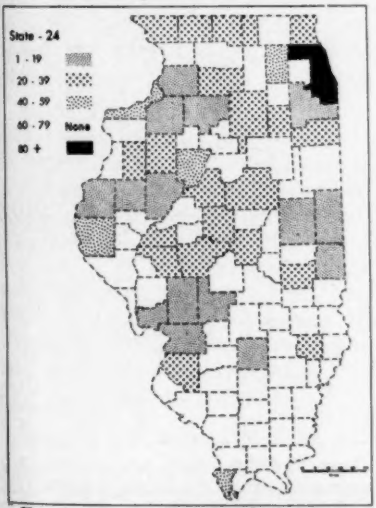

FIG. 1.—Per cent of population urban, 1870.

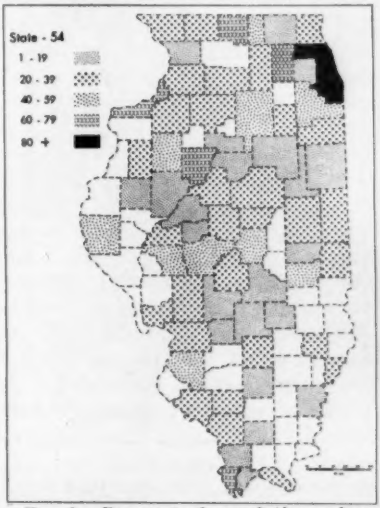

FIG. 2.—Per cent of population urban, 1900.

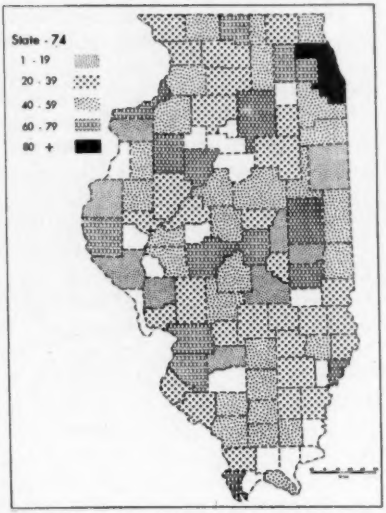

FIG. 3.—Per cent of population urban, 1950.

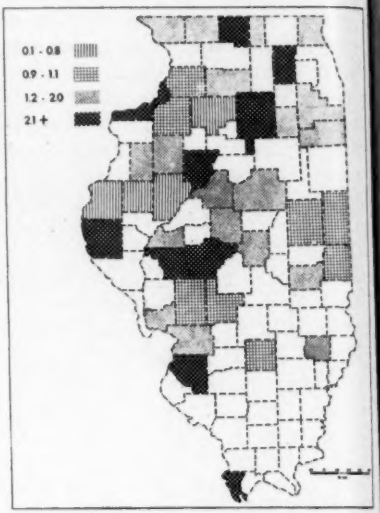

FIG. 4.—Location-quotient of urban population, 1870 (excluding Cook Co.).

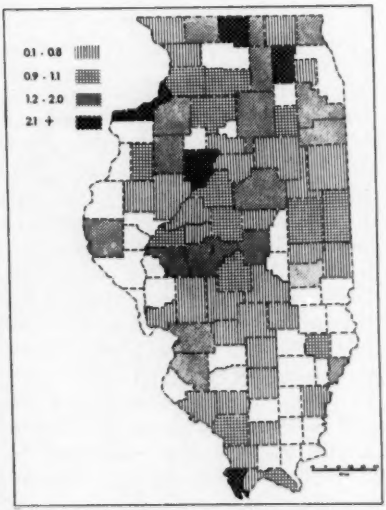

FIG. 5.—Location-quotient of urban population, 1900 (excluding Cook Co.).

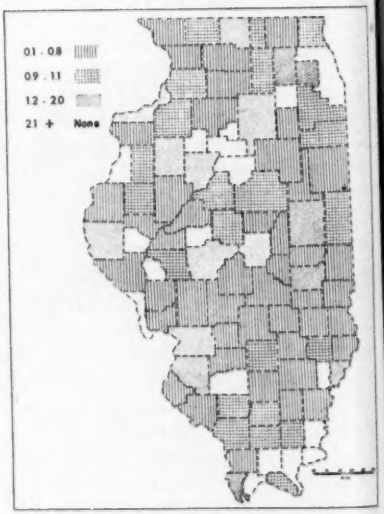

FIG. 6.—Location-quotient of urban population, 1950 (excluding Cook Co.).

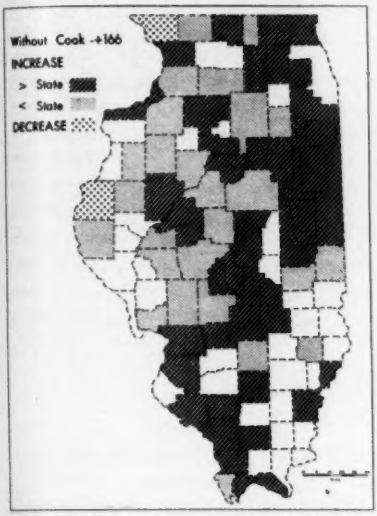

FIG. 7.—Per cent change in urban population, 1870-1900 (excluding Cook Co.).

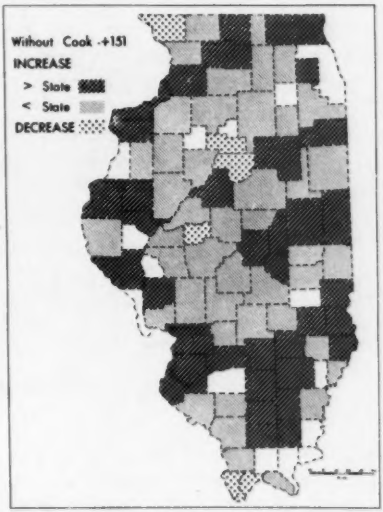

FIG. 8.—Per cent change in urban population, 1900-1950 (excluding Cook Co.).

to reach the 60% level in 1950. Thus, the main area of intensive urbanization had been established by the turn of the century. Few changes have been made in that pattern in the last 50 years.

By the end of the period 1870-1950, urban population was no longer confined to a few, mainly northern counties but was an important element in the total population of almost every county of the state. Patterns of the percentage of county population urban in 1870, 1900, and 1950 reveal the gradual spread of urbanism to all parts of the state and the increasing importance of city population in Illinois.

The gradual spread of urbanism throughout the state between 1870 and 1950 is particularly well shown by the analysis of urban population location-quotients for individual counties. (Such a location-quotient —the ratio between the importance of urban population to the state as a whole and the proportion of urban population within each county—indicates the location of the urban population throughout the state, not, as on the previous maps, the importance of urban population within individual counties). Since the purpose of this study was to trace the spread of urbanism throughout the state and since in a ratio like the location-quotient a single county of overwhelming magnitude destroys the sensitivity of the measure, Cook County was not included in this set of calculations. In 1870, excluding Cook County, 10 counties had location-quotients over 2.1 (Fig. 4). The very small number of counties with high quotients indicated the general lack of urbanization in the state and the concentration of a

FIG. 9.—Centers of urban population.

large proportion of all urban population in a few large centers.

Some of these same centers were still prominent in 1900 (Fig. 5), when Kane, Winnebago, Rock Island, Peoria, and Alexander—all containing large urban agglomerations—had location-quotients above 2.1. But these five counties all had quotients smaller than they displayed in 1870; further, Adams, Morgan, Sangamon, St. Clair, and La Salle had dropped from the highest class. By 1900, the state had become more widely urbanized. Almost all counties had some urban population. More cities had developed by 1900, and they were more widely distributed throughout the state.

The more widely spread the urban population, the more unusual is a high location-quotient for any one county. By 1950 (Fig. 6) the urban population was so spread that no county showed a quotient above 2.1, and fewer counties were in the second highest group than had been the case in either 1870 or 1900. Illinois had become a dominantly urban state which had practically no completely rural counties.

The transformation of various sections of Illinois from a rural to an urban status was not everywhere identical in timing. The percentage change in urban population is an excellent measure of the periods of intensive urbanization in various sections of Illinois. Between 1870 and 1900 (Fig. 7) 41 counties increased in urbanization at a rate greater than the state without Cook (166%); between 1900 and 1950 (Fig. 8) 37 counties urbanized more rapidly than the state (151%). In most instances, counties experienced major growth in urban population in one period or the other, not in both. Thus, only 14 counties in Group 1 (1870-1900) are also found in Group 2 (1900-1950). Since 9 of those 14 counties which became urbanized at a rate greater than the state in both periods are located in the northeast quadrant of Illinois, a net northeastward movement of the center of urban population is to be expected.

The greatest change in the pattern

of urbanization of Illinois came between 1870 and 1900. This was the period of greatest movement of the center of urban population calculated both with and without Cook County (Fig. 9). Even this movement (northeastward including Cook, southeastward excluding Cook) was moderate considering the extent of over-all urbanization of the state's population. Increasing urbanization was characteristic of all parts of the state and the "pull" of Chicago and the eastern half of Illinois was to a considerable degree offset by the growth of urban populations in the major centers elsewhere on the periphery of the state. The basic pattern of distribution of urban population was established by 1900; the centers in 1950 showed practically no movement.

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PATTERNS OF AGRICULTURAL CHANGE IN ILLINOIS

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The center of cropland harvested (Fig. 1) was located in 1930, and remained in 1954, near the geographical center of the state. The cropland center has shown practically no movement in the past 25 years. (Centers are determined by the method used by the Census Bureau.) From that relative lack of movement, it is evident that any changes in Illinois agricultural patterns are not changes in total cropland or in distribution of cropland. Nor does the behavior of this center show evidence of the much-discussed phenomenon of farm abandonment in the southern part of the state. In fact, the slight movement of the center since 1930 has been southward. (Also, there were 17 counties in Illinois harvesting fewer acres of cropland in 1954 than in 1930, and only 4 of these counties lay in the southern part of the state.) If any changes have occurred in Illinois agricultural patterns, they must, therefore, be changes in agricultural emphasis, reflecting differences in the comparative advantages of producing various crops.

Centers of Production or Distribution

However, an examination of the centers of production of most of the important crops and livestock specialties (Census Agric. data) shows that in most of these, as in the distribution of cropland, there was relatively little movement between 1930 and 1950 (Fig. 1). Thus it would seem that after a period which included a major economic depression and World War II, and during which there was constant technical progress in agriculture, the gross distributions of agricultural land, crops, and specialties are little altered. The findings of Case and Myers (1934) are still substantially correct, although they need a few important amendments.

There is an interesting concentration of the centers of production of various crops and livestock specialties near, but slightly north of, the geographical center of the state. The fact that this clustering occurs to the north of the geographical center simply emphasizes the greater agricultural output of the northern counties. The fact that the clustering occurs so near the geographical center implies one of three things: 1) an even spread of all types of agriculture over the state; 2) the concentration of all types of agriculture in the center of the state; or 3) balancing or offsetting areas of particular types of agriculture in various directions from the center.

The last of these three possibilities, offsetting areas in different directions from the center, is the basis for the clustering and the lack of movement of the centers of various crops as shown on Figure 1 and illustrated by the land-use maps in Case and Myers (1934). There are, how-

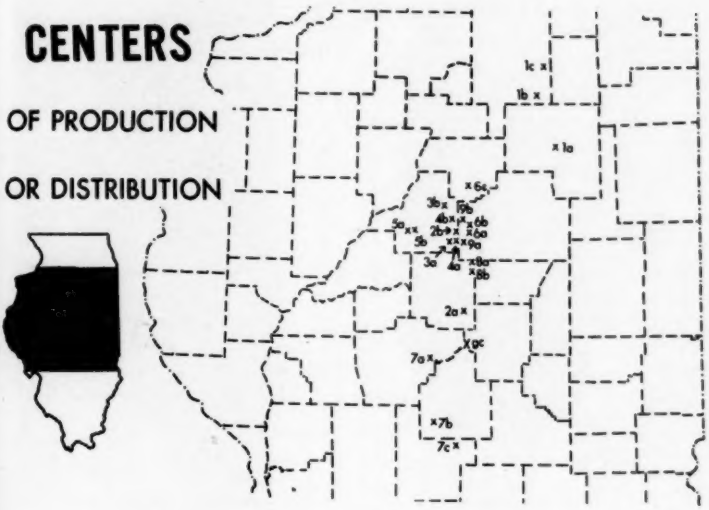

FIG. 1.—Centers of production or distribution:

1—vegetables for sale; 2—hay crops; 3—domestic animals; 4—cattle on farms; 5—swine on farms; 6—corn harvested for grain; 7—winter wheat; 8—crop land harvested; 9—value all products sold; *gc*—geographical center; *a*—1930; *b*—1950; *c*—1954.

ever, two kinds of exceptions to the clustering and stability of the centers. These exceptions illustrate significant changes in the patterns of agriculture in Illinois. Two centers, those of winter wheat and of vegetable production, are exceptional in their position, lying well outside the general cluster. Thus it is evident that production of these two crops is concentrated in one part of the state without balacing areas of production elsewhere. Wheat and vegetables, as well as domestic animals and hay crops, are also exceptional in that they showed distinct movements of their centers from 1930 to 1950. These movements are indicative of active changes in the patterns of agricultural land use. It may also be noted that while the center of corn production showed no movement between 1930 and 1950, the much-discussed northward movement of corn-growing made possible by hybridization shows up by 1954 as a result of the vast increase in the use of this type of corn since World War II.

PERCENTAGE CHANGES IN PRODUCTION BY COUNTIES

The only major southward movement among the mapped centers of production was that of winter wheat. The changes in crop patterns responsible for this movement are clearly shown on the 1930-1950 percentage of change map for this crop

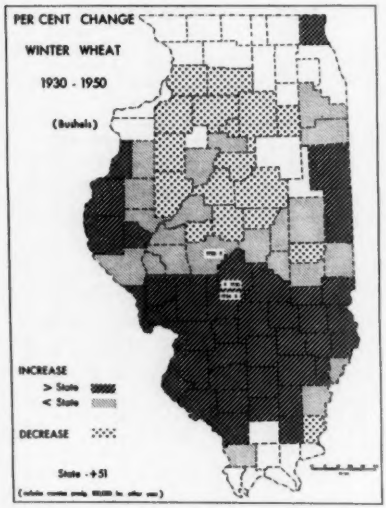

FIG. 2.—Per cent change in production of winter wheat (bushels).

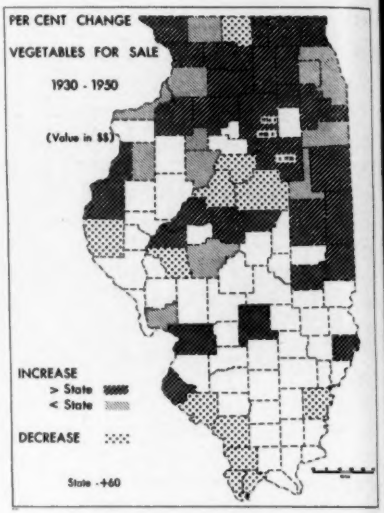

FIG. 3.—Per cent change in production of vegetables for sale (dollars).

(Fig. 2). Nearly all of the counties in the southern half of Illinois showed an increase in the production of winter wheat during this period. Most of the counties in the northern half of the state were areas either of decreasing production or where significant production had already ceased by 1950. An examination of recently available statistics for 1954 shows a continuation of these changes. In the 1950-1954 period there were three significant changes in the pattern of wheat production. Increases in east-central counties and decreases in southwestern counties moved the center of production eastward. Declines in a tier of counties just north of the center of the state resulted in a southward movement of the center. The net result of the changes over the past 25 years is a considerable movement of the center southeastward. It moved due south between 1930 and 1950, and to the southeast between 1950 and 1954.

All three of the other mapped centers exhibiting significant movement shifted to the north. The one which moved the greatest distance was the center of vegetable production. This specialty is obviously not as significant as many of the others in total acreage or even in value. It is, however, of particular interest because of its intensity, accompanying high land value, and traditional intimate relationship to urban areas. The major area showing an increase in the importance of vegetable production (Fig. 3) is a group of counties lying west of Chicago (Cook County). There is, however, no comparable area of increase surrounding Rock Island, Peoria, or East St. Louis (St. Clair County). The general increase in vegetable production in the north-

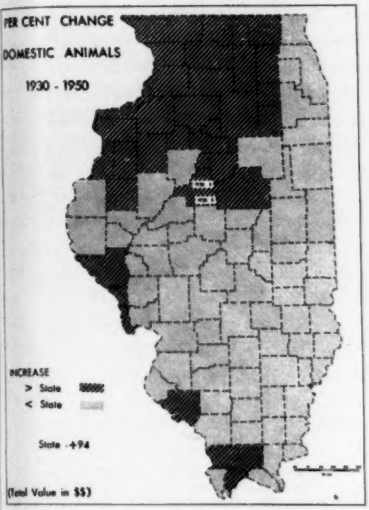

FIG. 4.—Per cent change in domestic animals on farms.

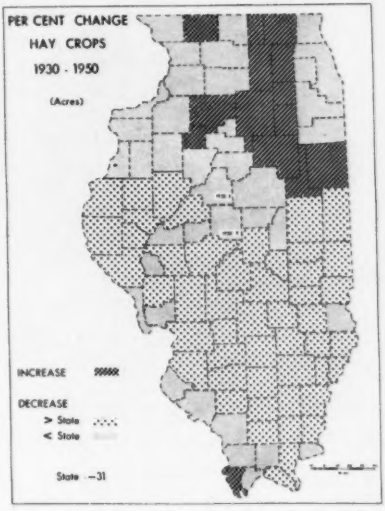

FIG. 5.—Per cent change in hay crops (acres).

ern one-third of the state accounted for the northward movement of the center. It seems apparent that easy access to the Chicago market is an outstanding factor. From 1950 to 1954 the center of vegetable production continued to move north and also shifted slightly east, reflecting the continuing pull of Chicago. There were noticeable decreases by 1954 in the western tier of counties in the north. Particularly noticeable since 1950 is the break of the old tie between truck gardening and the secondary urban centers of the state. All the counties surrounding East St. Louis decreased in production; similar decreases occurred around Rock Island; and the counties of east-central Illinois containing the cities of Champaign (Champaign County), Decatur (Macon County), and Mattoon (Coles County) also showed marked decreases in vegetable production.

The other two mapped centers which moved northward show changes in specialties which seem to have an obvious relationship—domestic animals and hay crops. The centers of these two distributions were much nearer together in 1950 than they were in 1930. The movement of the center of domestic animal distribution may be somewhat misleading since the only data available for both years are value figures. Changes in the general level of prices during the period 1930-1950 make it probable that the average state increase of 94.5% may actually mask a slight decrease in numbers of animals (Fig. 4). The movement of the center of hay production was accompanied by a sharp decrease in output, averaging 31% for the state

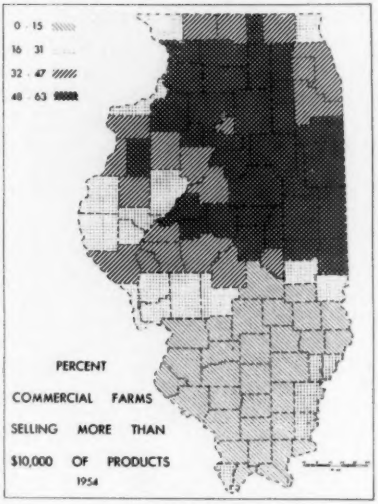

FIG. 6.—Per cent of commercial farms selling more than $10,000 of products in 1954.

(Fig. 5). These different rates of change lead to the conclusion that although the two agricultural items seem functionally related and their centers are close together, they are obviously not acted upon by the same forces in the same way. There was a greater-than-average increase in domestic animals in the whole northern third of the state with the exception of the eastern tier of counties. It is probable, however, that this general increase in the north reflects growth in two distinct activities—dairy cattle in those counties immediately west of the Chicago metropolitan area, and feeder cattle for meat production in the northwestern counties.

The general lack of movement of the mapped centers of most crops and livestock specialties indicates stability in gross agricultural patterns. The lack of movement suggests also that there has been no significant breakdown of the traditional distinction between commercial agriculture in the northern part of the state and a great deal of subsistence agriculture in the southern part of the state. In fact, of the four centers of commercial crops which moved significantly, three shifted northward. There may be, therefore, an increasing differential between the northern and southern sections of the state in commercial agricultural significance.

SUMMARY MEASURES OF CHANGE

Two further measures—value of all farm products sold and the distribution of the most productive commercial farms—are particularly indicative of the constant or increasing distinction between the agricultural economies of the northern and southern sections of the state. The center based on value of all farm products sold moved due northward, although the movement was not great (Fig. 1). Therefore, the three previously mentioned northward-moving crops or specialties more than offset in value the one southward-moving commercial crop, winter wheat. The increasing production of winter wheat in the south was not sufficient to affect materially the farm economy of the southern areas of low-value or subsistence agriculture. The other summary measure, illustrated by Figure 6 which shows the most productive commercial farms, again emphasizes the north-south contrasts within the state. Only in the northern half are farms selling more than $10,000 worth of products dominant among all farms.

By the same measure the farms of the southern portion of the state are dominantly non-commercial or at least produce a relatively low total value of product. (There is no direct correlation between average farm-size and average farm-productivity.)

Conclusion

The general patterns of agriculture in Illinois were much the same in 1950, and even in 1954, as they were in 1930. There was no major movement of the center of cropland harvested, and the centers of most crops and livestock specialties showed little movement, remaining clustered near the geographic center of the state. The only significant changes were in domestic animals, hay crops, vegetables, and winter wheat. In all of these except winter wheat, the areas of increase lay in the northern part of the state, and their centers of production moved northward. Examination of the center based on value of all farm products sold and of the distribution of commercial farms producing high values of products reinforces the idea of a sharp differentiation between predominantly large-scale commercial agriculture in the north and widespread subsistence agriculture or the production of less valuable products in southern Illinois.

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RAINFALL ON JAMAICA

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The areal and seasonal distribution of rainfall on the island of Jamaica in the British West Indies is affected by three major interacting controls: 1) location of highlands in the eastern and western portions of the island; 2) existence of seasonal changes in wind direction; and 3) periodic occurrence of tropical hurricanes.

Areal Distribution of Rainfall

Highlands are extremely important in the distribution of rainfall on Jamaica. The two largest highland areas over 3,000 feet in elevation, in eastern and western Jamaica, are both areas of heavy rainfall, as shown in Figure 1 (U. S. Weather Bureau, 1921-1952). The Blue Mountains in the east, the higher of the two areas, have the greater effect on the distribution of rainfall on the island.

In the Blue Mountains, where peaks over 6,000 feet stand within only 15 miles of both the north and south coasts, differences in rainfall between places on the north and south slopes of the mountains are very great. Both the wettest and the driest stations in Jamica are located in this area. Within a distance of only 30 miles, between Fellowship to the north and Kingston to the south of the mountains, there is a difference in average annual rainfall of over 130 inches (Table 1). Fellowship, on the wet northeastern slopes, has the highest annual rainfall on the island, more than 160 inches. Totals of more than 200 inches have been recorded there in some years. Two of the three other island stations recording more than 100 inches annually are on the northeastern slopes of the Blue Mountains, and the third is in the western highlands. Much of the highland rainfall is orographic, dropped when warm, moist, marine air is moved up the mountain slopes. Thus, the wettest areas in Jamaica are located in or near the two highlands; the driest areas are located along the northwestern and, especially, the southern coasts. Only 30 miles to the southwest of Fellowship, the city of Kingston, on the southern slope of the mountains, has a mean annual rainfall less than 30 inches, the lowest total recorded on the island.

Seasonal changes in atmospheric conditions and prevailing winds combine with the location of highland areas to affect the areal distribution of rainfall on Jamaica (Ward and Brooks, 1934:13-17). The winds throughout the year are easterly, coming from the "Azores" or "Bermuda" High. Variations from northeast to southeast, however, are associated with the periodic shifting of this high and the development of a low pressure area over the western Gulf of Mexico and the United States. With the advance of sum-

TABLE 1.—Average Monthly and Annual Rainfall on Jamaica*

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Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Island average	3.47	2.62	2.65	4.81	8.99	6.51	5.73	7.84	7.95	10.43	8.00	4.84	72.15
Fellowship	11.80	9.10	5.47	9.56	14.85	13.63	14.30	14.08	13.25	17.54	23.13	16.47	160.74
Port Antonio	8.69	5.75	4.19	6.83	12.23	11.33	11.76	11.87	11.77	15.12	16.77	9.97	126.26
Darliston	3.12	3.65	5.13	11.37	17.99	11.94	12.32	17.39	15.06	16.48	8.04	3.14	124.82
Bath	6.15	4.24	3.25	5.63	10.73	11.09	8.93	11.56	13.75	18.50	13.79	9.36	116.99
Buff Bay	8.26	7.09	4.35	6.30	9.54	5.04	6.59	6.63	5.53	8.98	14.51	10.99	93.80
Cambridge	1.85	2.63	4.09	7.33	12.68	10.53	8.96	11.38	11.72	11.84	5.53	2.17	90.69
Stony Hill	2.06	2.62	2.01	4.99	8.10	5.16	5.06	9.31	14.96	13.24	8.24	3.25	78.99
Balaclava	1.78	3.23	4.09	8.61	11.95	4.74	5.03	9.58	9.12	13.06	5.45	1.95	78.99
Kempshot	2.99	2.69	2.87	5.05	10.44	8.20	5.50	6.78	8.04	10.04	8.88	3.39	75.29
Christiana	2.27	3.07	2.89	6.63	9.71	5.41	4.14	7.55	7.85	11.86	5.78	2.03	69.25
Morant Bay	2.69	1.52	1.40	2.44	6.70	7.48	5.51	7.22	9.75	12.30	7.30	3.83	68.14
Port Maria	5.49	3.81	3.57	3.83	6.45	3.38	3.80	5.22	4.83	7.68	11.06	7.74	66.85
Linstead	2.27	2.42	2.46	4.39	7.68	6.47	5.92	7.34	7.09	8.41	5.56	2.73	63.54
Morant Point Light	3.50	2.56	1.73	3.15	5.82	5.02	3.52	5.86	7.35	12.06	8.13	4.48	63.37
Savannah La Mar	1.74	1.97	3.25	4.71	8.07	6.17	6.17	7.21	7.49	8.35	3.67	1.83	61.15
Saint Ann's Bay	5.59	4.21	3.29	3.61	6.02	3.52	2.37	3.74	3.61	6.55	8.98	6.62	58.85
Chapelton	1.62	1.99	1.99	3.53	8.31	5.01	3.87	6.00	7.45	11.58	5.34	1.64	58.71
Negril Point Light	2.25	1.74	2.82	3.70	6.35	5.26	5.59	6.27	5.82	8.00	3.05	1.85	52.70
Montego Bay	2.64	1.68	1.89	2.90	6.75	5.36	2.99	4.85	6.16	7.09	6.25	2.73	51.81
Black River	1.97	1.78	2.17	3.83	5.99	3.67	4.00	6.04	4.91	8.09	4.32	2.04	49.19
Old Harbour	1.64	2.24	1.67	3.21	5.22	3.64	2.79	6.45	5.88	9.55	5.00	1.89	48.89
Alligator Pond	1.03	1.73	1.65	2.83	3.96	2.70	2.48	4.64	5.62	8.02	4.33	1.56	40.49
Spanish Town	1.01	1.69	1.37	2.41	4.29	2.71	1.89	4.67	4.33	8.12	4.62	1.50	38.82
Falmouth	2.15	1.95	1.71	2.32	3.69	2.67	1.70	2.85	3.30	5.79	6.08	3.19	37.71
Kingston	0.67	0.88	0.49	1.12	2.59	2.65	2.02	4.86	4.46	5.95	3.34	0.96	29.88

* Data in this table compiled from U. S. Weather Bureau, 1921-1952.

mer, southeasterly winds develop as the air flows into the North American low. With the onset of winter, the North American low disappears and the winds shift to the northeast. As the winds are shifting to the southeast in May or June, and to the northeast in September or October, two periods of relative calm occur. At these times, convectional thundershowers bring large amounts of rainfall to all parts of Jamaica (Table 1). Ordinarily, convection is greatest in October which is the wettest month for the island; another period of active convection comes in May or June, giving rise to a secondary maximum over the island at that time.

Occasional tropical hurricanes may augment the October rainfall maximum on Jamaica. The highland areas often receive the greatest amounts of rain from these storms, but the effects of hurricanes are felt over the entire island. In the hurricane season, August to December, monthly amounts of 30 inches have been recorded in the western uplands, while monthly amounts in excess of 60 inches have been recorded in and near the eastern highlands. One exceptional storm in November, 1909, dropped a reported 94 inches of rain in only three days at Silver Hill Plantation in the Blue Mountains (Ward and Brooks, 1934:15). Even at Kingston, in the driest area of Jamaica, 17 inches of rain, or over one-half of the mean annual rainfall for the station, were recorded in one day during the passage of a hurricane in 1951.

Tropical hurricanes add markedly to the variability of rainfall on Jamaica. The periodic occurrence of hurricanes establishes for all stations average annual rainfalls which are not equalled in most non-hurricane years. When no storms occur, stations on the island record rainfall below averages, and dry conditions may follow. When hurricanes do occur, floods and serious crop losses may result, and the island stations record rainfall above the average.

Seasonal Distribution

Topography, prevailing easterly winds, and hurricanes are controls of the areal distribution and annual variability of rainfall on Jamaica. With the exception of topography, they are also the controls of the seasonal distribution of rainfall on the island. Monthly and annual rainfall for all stations on the island have been compiled and recorded in Table 1.

For most of the island the wettest season of three consecutive months comes in August, September, and October; on the north and northeast coasts the wet period occurs later (Fig. 2). The heaviest rainfall occurs in late summer and autumn when both the land and the water off which the winds come are warmest, convection is most active, and hurricanes occur. Mean rainfall during the three consecutive wettest months varies from 57 inches at Fellowship in the northeast, and 39 inches at Darliston in the west, to 15 inches at both Kingston in the south and at Falmouth on the north coast. The wettest individual month varies from October in the central and southern areas to November along the northern coast (Table 1). Rainfall in individual wet months ranges from 23 inches at Fellowship to

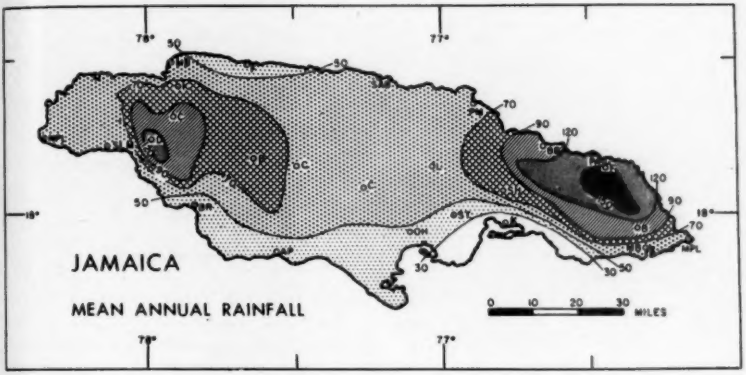

FIG. 1.—Mean annual rainfall on Jamaica.

about 8 inches at many stations in the south.

A secondary wet season exists throughout the island in the period between mid-April and mid-August. This wet season is shorter in length and corresponds to the other period of shifting wind direction and strong convection. The secondary wet season is most important in the west, but many island stations record a secondary rainfall maximum in May or June. An exceptional area in the western highlands receives its greatest monthly rainfall in May, even though the wettest three-month season is from August through October.

The time of occurrence of the driest season varies areally more than the time of occurrence of the wettest season. The dry season occurs between mid-December and mid-April when nearly all hurricane activity has ended, convection is almost completely absent, and strong northeasterly winds prevail. During the three consecutive driest months (Fig. 3) mean rainfall varies from 24 inches at Fellowship to less than 2 inches at Kingston. Some northeastern slopes, such as those near Fellowship, receive considerable amounts of rainfall even during the dry season. An exceptional area along the north coast has its driest season in June, July, and August, although it is nearly as dry in January, February, and March. Total rainfall is lowest over the entire island in March, but January is the driest month in central Jamaica, and February is the driest month in the west (Table 1).

Occasional drouths resulting in serious crop damage have occurred on the north and south coasts. For example, only 0.34 inches of rain were recorded at Kingston during the five-month period from December to May, 1944, and at Falmouth on the north coast only 0.11 inches of rain were recorded in one four-month period. Seventeen of the 25 stations in the study, including Fellowship in the wettest area on the island, have sometimes recorded no rainfall for a period of at least one month.

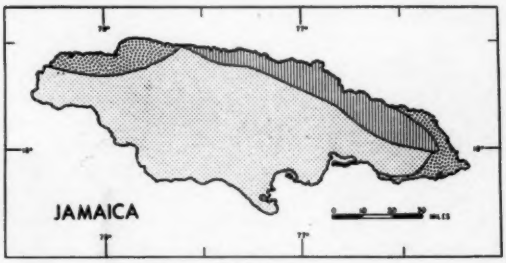

FIG. 2.—Wettest three-month season on Jamaica.

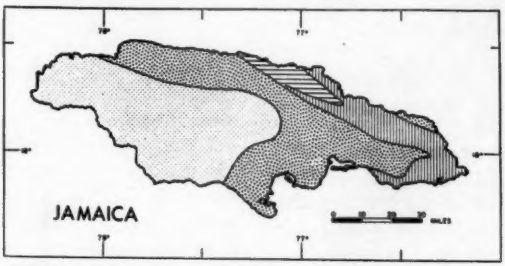
JAMAICA
DRIEST THREE MONTH SEASON
DECEMBER - JANUARY - FEBRUARY
JANUARY - FEBRUARY - MARCH
FEBRUARY - MARCH - APRIL
JUNE - JULY - AUGUST

FIG. 3.—Driest three-month season on Jamaica.

SUMMARY

The gross pattern of rainfall distribution on Jamaica is associated with three factors: topography, changes in wind direction, and periodic hurricanes. The wettest areas are on windward slopes; great contrasts in rainfall, associated with topographic features, are to be found within very short distances. Tropical hurricanes bring large amounts of rainfall in some years, and none in others, so that extremely wet or dry years may occur in the same locality. Differences in the direction and velocity of winds, in atmospheric pressures, and in the numbers of convectional storms are important to the details of the distribution of rainfall on Jamaica. Local irregularities in rainfall distribution still call for further investigation.

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URBAN AND NON-URBAN ASPECTS OF MANUFACTURING IN ILLINOIS

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Manufacturing in Illinois is overwhelmingly an urban activity. Despite the establishment of some new industries in rural areas during the Second World War, the number of urban production workers declined only slightly—from 90% of total production workers in 1939 to 88% in 1947. Also, manufacturing in Illinois is primarily an activity of the northern, more urbanized, portion of the state. Since neither urbanization nor manufacturing is completely confined to northern Illinois, or evenly distributed within any section of the state, all parts of Illinois show considerable county-by-county variation in the proportion of non-urban to total production workers. Even non-urban manufacturing is centered in the northeastern quarter of the state, since the highly urbanized and industrialized counties—particularly Cook—also have a disproportionately high percentage of the state's total non-urban employment.

Centers of Manufacturing

The centers of total manufacturing (Fig. 1), including both urban and non-urban production workers, give evidence of the importance and the consistency of the pull of Cook County by their locations in the northeastern portion of the state and by their almost complete lack of movement between 1939 and 1951. Not only is manufacturing in Illinois primarily an urban activity, but also it is primarily an activity of Cook County and the Chicago area. Data of the departments of Commerce and Health, Education, and Welfare indicate that in all three of the base years (1939, 1947, and 1951) Cook County alone accounted for 66% of the state's production workers. This dominance of a single county so affects the analysis of the total manufacturing pattern that the relative positions of other sections of the state in that pattern cannot be adequately visualized. In a very real sense, the inclusion of Cook County in the centers of manufacturing compares other counties, not with the state as a whole, but with Cook County almost alone.

A more revealing analysis is, therefore, obtained from the center of total manufacturing when Cook County is excluded (Fig. 1). Even without the northern attraction of this one dominant county, the strong influence of the northern one-third of the state is seen. The absence of the eastern pull of Chicago is indicated by the location of the center, without Cook, very close to the north-south axis of the state. Excluding Cook County the centers of total manufacturing are, for all three years, as tightly clustered as are the inclusive total centers. The distribution of manufacturing activity throughout the state, then, has

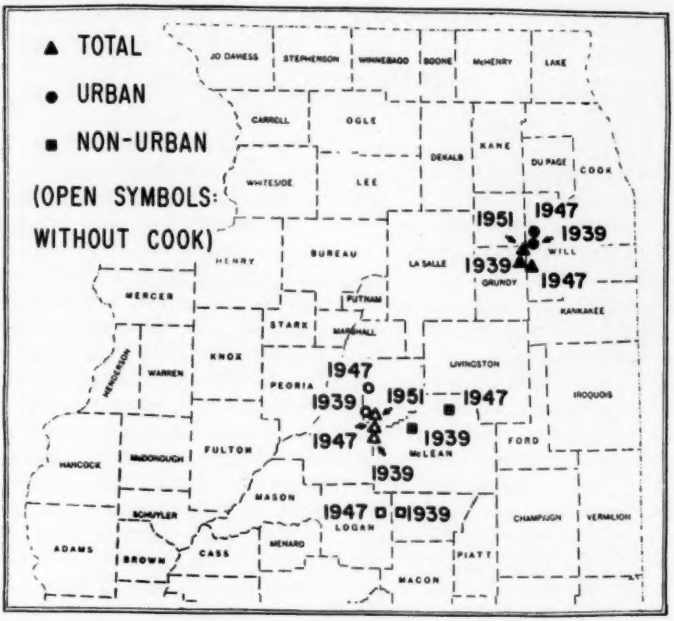

FIG. 1.—Centers of manufacturing (based on production workers).

shown as little relative change during the Second World War and the Korean conflict as did manufacturing in Cook County alone.

It should be noted that the distance between the Cook and without-Cook centers of manufacturing exaggerates Cook County's absolute position in the industrial pattern of the state. The center of manufacturing is a graphic mean; like all means it has inherent in it the disproportionate attraction of the extremes. Since Cook County is an extreme in both number of workers and distance from the center point of the state, it influences the center of manufacturing disproportionately.

The centers of total manufacturing do not distinguish between the relative effects on the center of areas of urban and non-urban manufacturing. Those separate attractions are illustrated by calculating centers of manufacturing for both types of industrial location and by comparing these with the total center of manufacturing. Such a comparison is possible on Figure 1. Through the close association of the urban and the total centers of manufacturing, the dominance of urban manufacturing locations in Illinois is indicated. The pull northeastward of the center of urban manufacturing is understandable as another indication of Cook County's dominance in the state pattern. This single county contained, in both 1939 and 1947, 71% of the urban manufacturing

workers in Illinois. Excluding Cook County, there was very little difference between the urban and total centers—again emphasizing the importance of the urbanized northern one-third of the state and the dominantly urban nature of Illinois' manufacturing.

The centers of non-urban manufacturing for the whole state in both 1939 and 1947 lay very close to both the urban and total centers, excluding Cook County. This spatial correlation indicates that Cook County's attraction on the total center is much reduced when only non-urban manufacturing locations are considered. Yet, that dominantly urban area did have a significant amount of non-urban manufacturing, and its importance as a focus of non-urban industry increased between 1939 and 1947; the movement to the west of the non-urban center of manufacturing excluding Cook County suggests that county's increasing degree of importance even in this type of manufacturing, while the decided movement northeastward of the total non-urban center suggests that Cook County's rural establishments increased in number or size disproportionately to those in the rest of the state between 1939 and 1947. Since the relative influence of Cook County on both the total and urban centers remained virtually static through the years considered, but became increasingly important in non-urban manufacturing, it may be suggested that deconcentration—*i.e.*, "ruralization"—of industry, at least prior to 1947, was largely confined to the immediate vicinity of Chicago. The non-urban center of manufacturing without Cook moved due west, not due north as was the case in other centers of manufacturing.

The locations of these centers of manufacturing, based upon the number of manufacturing production workers in Illinois, serve to summarize the relative importance of the various sections of the state in both urban and non-urban manufacturing patterns. The locations of centers do not, however, indicate the importance of different manufacturing sites within a single county; nor do they suggest the relative positions of individual counties in total, urban, or non-urban manufacturing activities. Two additional sets of maps—one showing the percentage of the various counties' production workers who were non-urban, and one indicating the percentage of the state's non-urban production workers located within any one county—clarify these points.

Characteristics of Individual Counties

The data on Figures 2 and 3, and their implied urban counterparts, indicate the relative significance of urban and non-urban manufacturing locations within the 102 counties of Illinois. In neither Figure 2 (1939) nor Figure 3 (1947) is there a readily discernible pattern. There is no one section of the state which uniformly displays a high (more than 30%) proportion of its production workers employed at non-urban locations. Rather, there is a wide scattering of such largely non-urban manufacturing counties in both the urbanized north and the primarily rural south. In fact, in 1939, the largest clustering of "high non-urban" counties lay along the east-

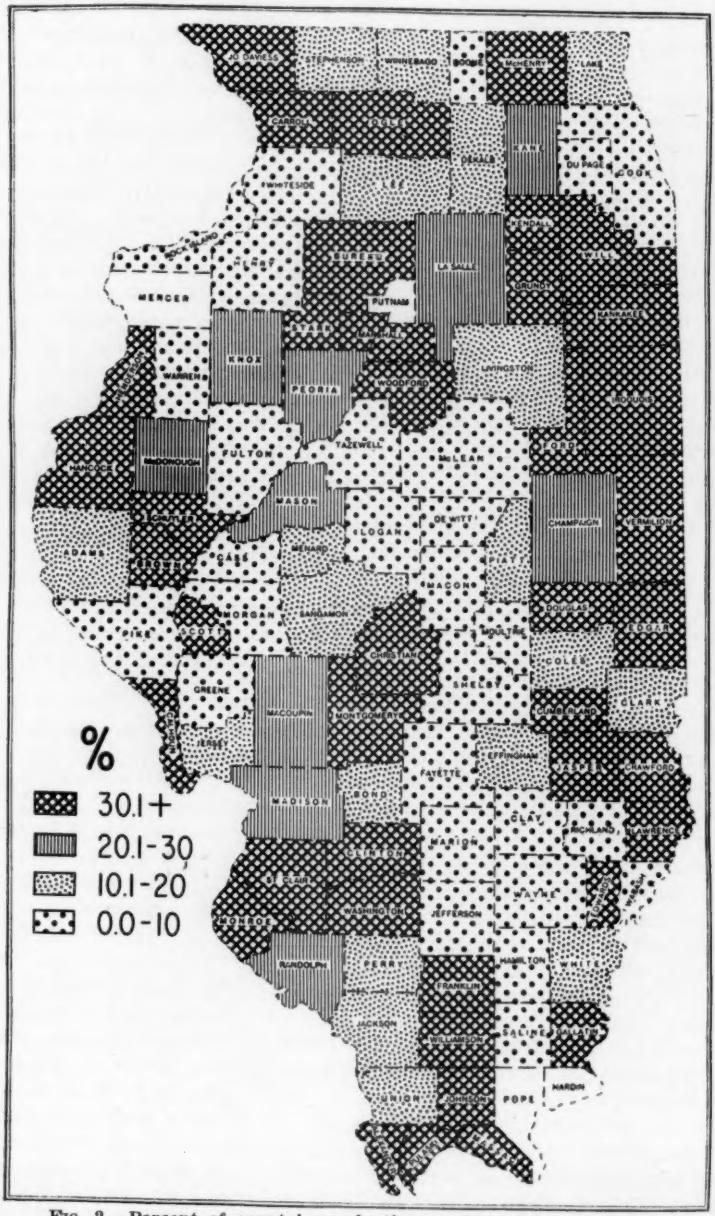

FIG. 2.—Percent of county's production workers non-urban, 1939.

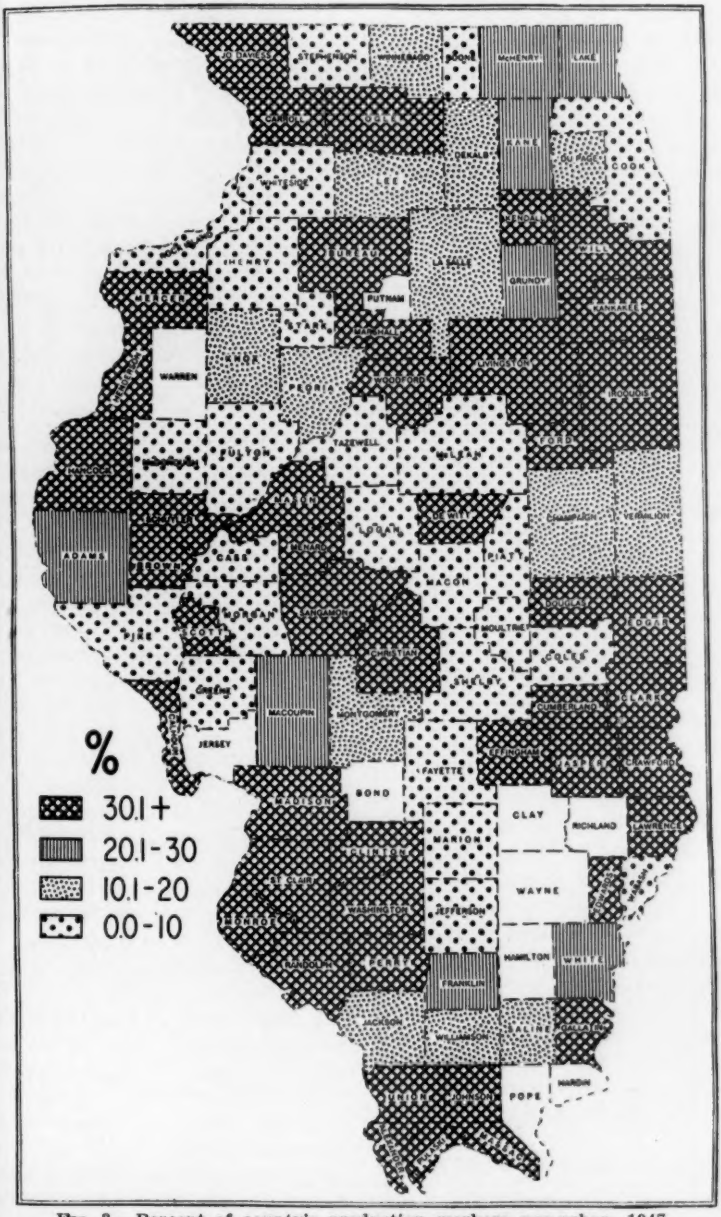

FIG. 3.—Percent of county's production workers non-urban, 1947.

ern margin of the state and straddled any such north-south division line. Noteworthy on Figure 2 are the rather different positions of the main urban counties of the state. Cook County (Chicago) with 4.0% of its production workers non-urban; Rock Island (Rock Island and Moline), 0.5%; and Tazewell (East Peoria and Pekin), 3.9%, have very low proportions of production workers non-urban. Winnebago (Rockford) (12.6%), Sangamon (Springfield) (17.6%), and Peoria (Peoria) (24.8%) occupy middle positions while St. Clair (East St. Louis) (49.2%) was very high in proportion of production workers non-urban in 1939. Apparently, a large manufacturing city is, of itself, no guarantee that a county's manufacturing workers will be primarily urban. This lack of accordance was accentuated during the Second World War.

In 1947, as can be seen from Figure 3, there was an increase in the number of counties with more than 30% of their workers non-urban, suggesting an increase in industrial deconcentration throughout the state. Counties with large cities generally reflected that increased "ruralization". Cook County in 1947 had 4.8% (up from 4.0) of its total production workers non-urban, and Winnebago increased to 17.1% (up from 12.6). St. Clair and Sangamon counties significantly increased their proportions of non-urban workers. Rock Island remained unchanged and only Peoria and Tazewell counties decreased.

Dominant Industrial Counties

These county patterns of the percentage of workers non-urban do not furnish evidence to explain the northeastern location of the non-urban center of manufacturing. Nor could the data be expected to provide such an explanation, since they are descriptive only of the counties' internal arrangement of workers. On the other hand, Figures 4, 5, and 6—more closely related to the center of manufacturing analysis—do illustrate the reasons for the northeastward pull of the non-urban center of production and display the position of the respective counties in the state's total industrial picture.

In 1939 (Fig. 4) there were only two clusters of counties which had more than 3.6% of all the state's non-urban production workers. The more important of these clusters was in the northeast—in Cook County and the Chicago metropolitan area, with LaSalle County almost adjacent. The three metropolitan district counties (Cook, Kane, and Will) contained 35% of the entire state's non-urban production workers. Cook County alone had 25%. This cluster accounts for the strong northeast pull of the non-urban center of manufacturing in 1939. This concentration in the northeast completely outweighed any claim to non-urban industrial dominance that Figure 2 may have implied for the southern two-thirds or the eastern tier of counties of the state. The only other block of counties having a significant share of the state's non-urban workers includes Madison and St. Clair in the East St. Louis area. Thus, the pattern of relative importance of counties in Illinois' total non-urban manufacturing picture, shown on Figure 4, suggests that

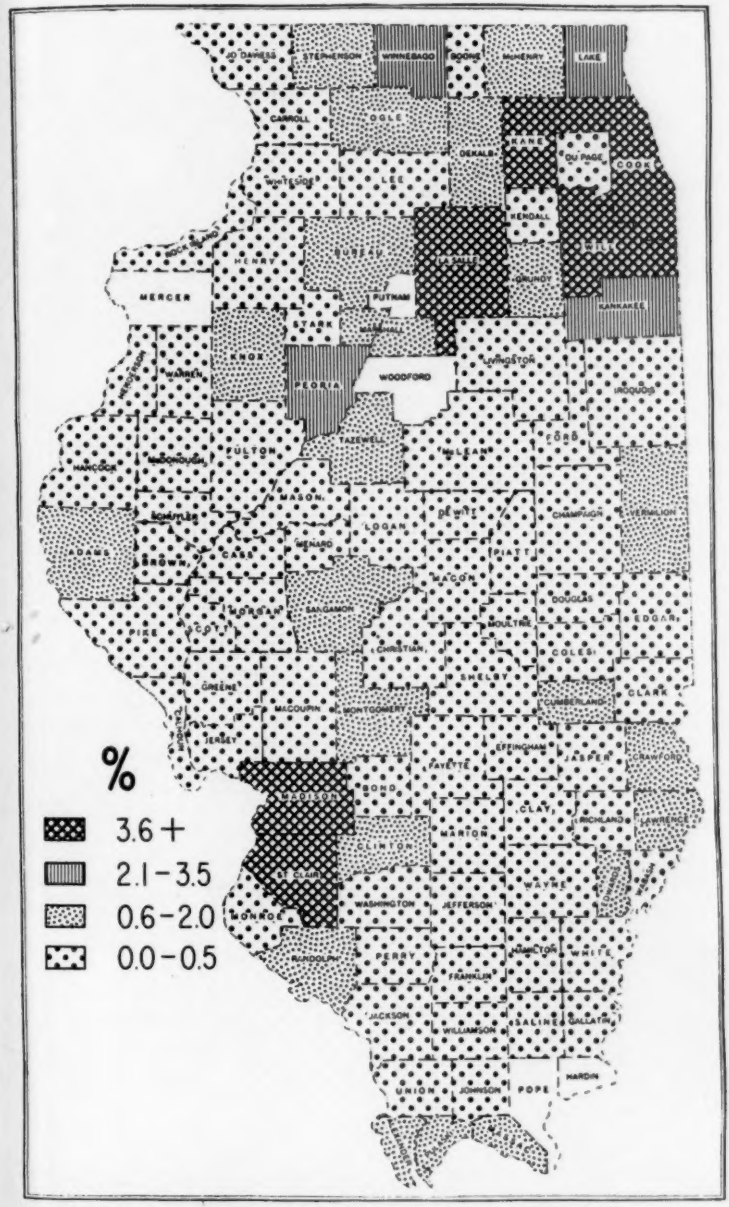

FIG. 4.—Percent of state's non-urban workers, 1939.

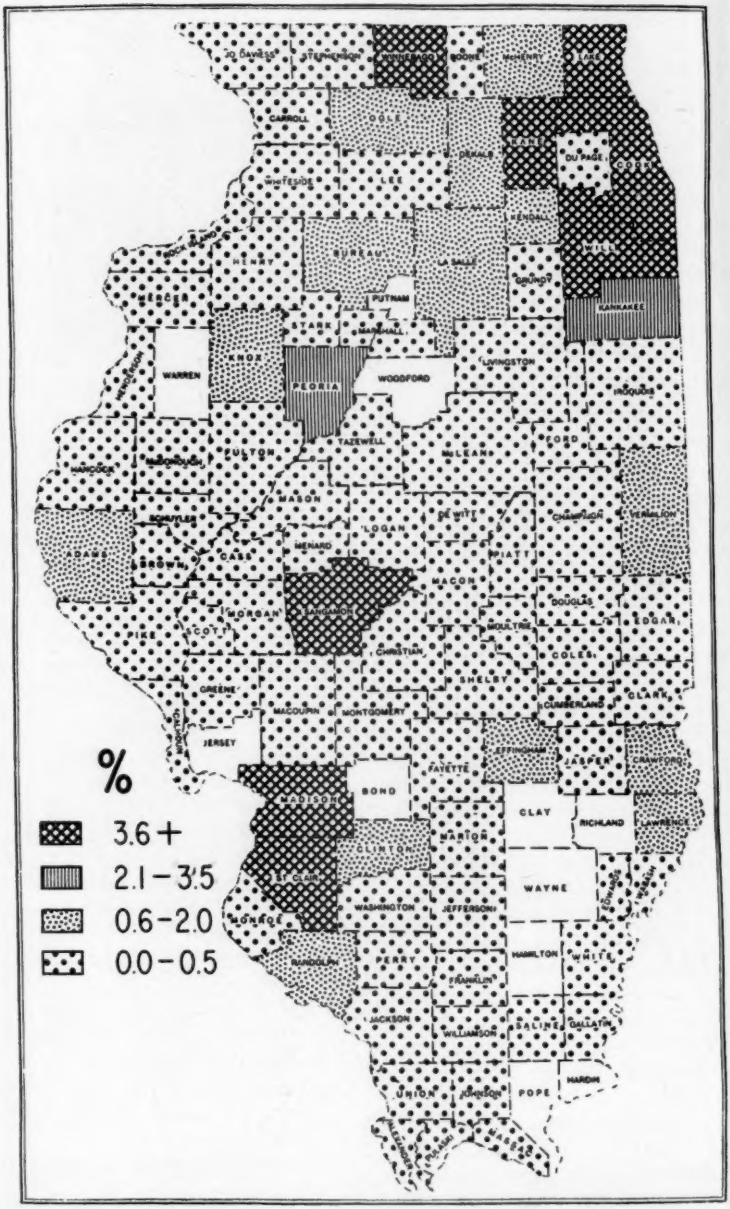

FIG. 5.—Percent of state's non-urban workers, 1947.

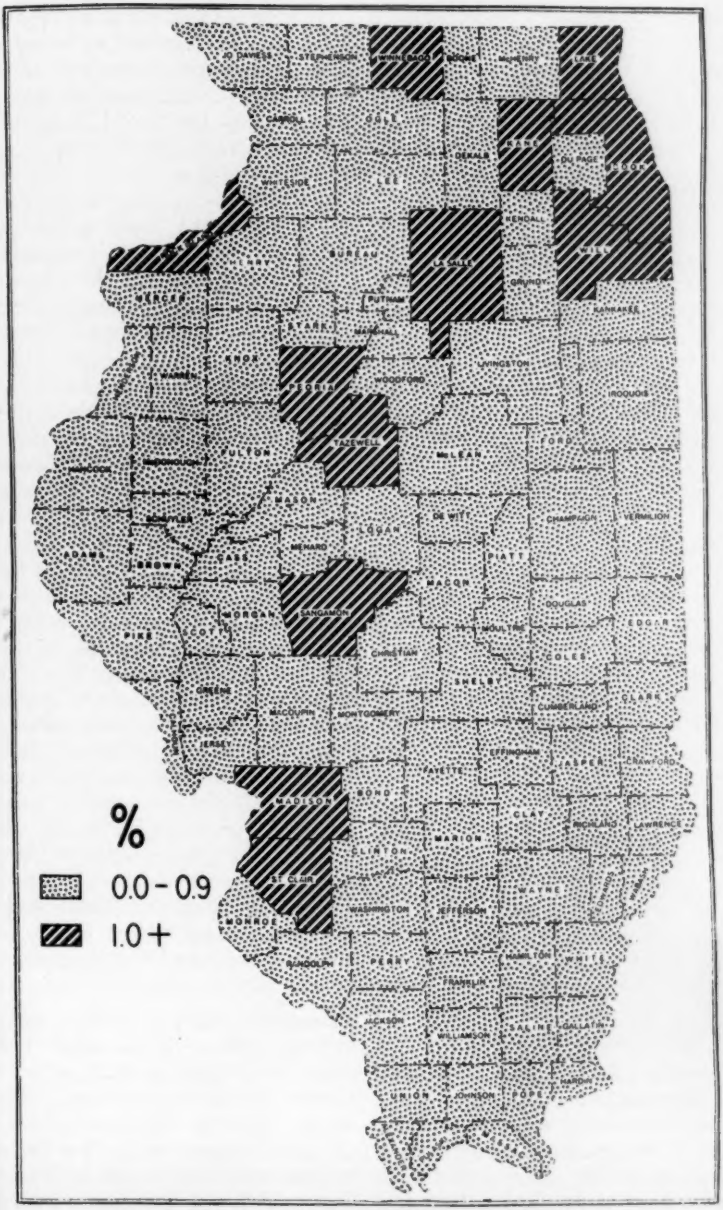

FIG. 6.—Percent of state's production workers, 1947.

many of the counties which seemed important in their percentage of non-urban workers to total workers were not at all significant as industrialized counties.

In 1947 (Fig. 5) much the same picture of concentration of the state's non-urban production workers in a very few counties was again evident. The Chicago metropolitan area again dominated and now included Lake County. Cook County increased its share of the state's non-urban workers from 25 to 28%, while Will County declined though it still remained in the top group. LaSalle, outside of the metropolitan area, fell from the group of highest concentration between 1939 and 1947, but two of the major urbanized counties (Winnebago and Sangamon) experienced a considerable proportionate increase of non-urban workers. In other urban areas, both Peoria and Tazewell counties dropped, while in the East St. Louis district St. Clair County increased and Madison decreased in their shares of Illinois' non-urban workers. A comparison of Figure 5 with Figure 6, which shows the location of major industrialized counties of the state, indicates that by 1947 the developing pattern seemed to be that the major industrialized and urbanized counties accounted for an increasing share of the state's total non-urban workers; only the Peoria and Rock Island areas and LaSalle County were exceptions.

The data presented thus far in this study have all been based upon "production workers" and so take no account of the locations of *establishments*. Although these latter are not discussed in detail here, the patterns for the percentage of the counties' establishments that were non-urban and the percentage of the state's non-urban establishments in each county are almost identical to the patterns of distribution of production workers already displayed. Whichever set of data is employed, apparently, the basic pattern of county characteristics is unaltered, and all data indicate the manufacturing dominance of the primarily urban, rather than rural, counties of the state.

It is evident from Figures 4 and 5 that industry had not, up to 1947, moved out into the rural counties of Illinois. The previously industrialized and non-urban areas in general lost, rather than gained, in relative numbers of production workers. The close spatial association of the total centers of production in 1939, 1947, and 1951 indicates that that situation remained unchanged at least through the Korean conflict which also included the Federal government's active program of encouragement of industrial dispersal. Nonetheless, for the state as a whole, there were 70.7% more non-urban workers in 1947 than in 1939; in the same period total production workers for the state increased by only 61.5%. Therefore, Illinois' manufacturing during that eight-year period, including the Second World War, had become slightly less urbanized.

Since the majority of the counties had in 1939, and retained in 1947, only a very small percentage of the state's non-urban workers, it becomes apparent that Illinois' overall gain in non-urban production workers was largely concentrated in those urbanized counties which in

1947 contained the largest numbers of non-urban workers and which were in 1947 the most highly industrialized (Fig. 6).

The expansion of non-urban manufacturing in the principal industrial counties is summarized in Table 1 (based on Bureau of the Census statistics for 1939 and 1947). As indicated by data in the table, in 1947 those counties which were highly industrialized also contained a high proportion of the state's non-urban production workers. Any increase in the relative importance of non-urban manufacturing in these counties would, therefore, account for most of the increase in non-urban industrial activity in the state as a whole. Five of the six industrialized counties included in the first half of Table 1 had a top ranking in 1947 in percentage of Illinois' non-urban production workers (Fig. 5). Only one of the six (Lake) was not a central city county (granting the equivalence of central city status to East St. Louis, St. Clair County), and all six had an increase in non-urban workers that was greater than their increase in total production workers. These counties, then, are those in which "deconcentration" of industry was most important in Illinois between 1939 and 1947 and most affected the over-all state pattern of increasing non-urbanization of manufacturing.

Only three of the six industrialized counties in the second half of Table 1 had high ranking in non-urban production workers in 1947 (Fig. 5); only one (Peoria) was a central city county, and all had a percentage increase in non-urban workers which was less than their increase in total production workers. These counties, then, did not contribute to the state pattern of slight increase in non-urban manufacturing between 1939 and 1947.

TABLE 1.—Industrialized Counties: Percentage Change in Total and Non-Urban Production Workers, 1939 to 1947.[1]

County	Production workers	
	Total percentage change	Non-urban percentage change
Sangamon[2]	+123.8	+397.7
Lake[2]	+ 94.4	+185.5
Winnebago[2]	+ 64.3	+123.3
Cook[2]	+ 60.9	+ 93.2
St. Clair[2]	+ 62.1	+ 91.6
Rock Island	+ 55.4	+ 60.9
Madison[2]	+ 62.0	+ 47.4
Kane[2]	+ 57.6	+ 46.1
Tazewell	+ 97.8	+ 43.8
Will[2]	+ 47.8	+ 21.7
Peoria	+ 64.8	+ 3.9
LaSalle	+ 65.6	— 32.7

[1] Those counties having 1.0% or more of the state's production workers in 1947. *Cf.* Fig. 6.
[2] Had more than 3.6% of the state's non-urban production workers, 1947. *Cf.* Fig. 5.

SUMMARY

Manufacturing remained a predominantly urban activity in Illinois, at least through 1947, despite the greater than average percentage increase in the number of non-urban workers in a few highly industrialized counties. Since urban production workers accounted for 90% in 1939 and 88% in 1947 of all production workers, the northeastern locations of the centers of manufacturing are understandable as the result of the attraction northward by the most urbanized section of the state and northeastward by the most ur-

banized and industrialized county. That same general directional pull is still encountered when only non-urban production workers are considered. Although the urbanized and industrialized counties of the north and northeast have relatively low percentages of their total workers in non-urban manufacturing, they contain the major share of the state's total non-urban production workers.

Acknowledgment

The research on which this study is based was supported in part by funds granted by the Research Board of the Graduate College of the University of Illinois.

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GEOLOGY

PLASTICITY STUDIES OF TILL INTRUDED INTO JOINTED LIMESTONE IN FAIRMOUNT QUARRY, ILLINOIS

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For a number of years limestone for road metal and agricultural use has been quarried about three miles southwest of the village of Fairmount in east-central Illinois (Fig. 1). The quarry is in the Livingston limestone in the upper part of the McLeansboro group of the Pennsylvanian System.

The limestone occurs as a small outlier north of the main area of Livingston on a small anticline on the east flank of the major structural feature, the LaSalle Anticline. The overburden of 15 to 20 feet of glacial till with a thin mantle of loess is removed by stripping.

The upper surface of the bedrock is nearly flat and contains two conspicuous and a third minor set of striations; one set trends about S 10° W, one about S 45° W, and the minor set trends southeast.

Essentially vertical openings a few inches to several feet wide and up to about 10 feet deep were formed by solution along joints in the thin-bedded limestone. The joint system is composed of two sets, one set trending N 63° E and the other about N 25° W. The enlarged joints are filled with several different kinds of material which aid in the interpretation of the post-Paleozoic geological history of the region. The filled joints and the glacial striations on the stripped surface of the limestone are visible in Figure 2.

The Pleistocene deposits in the Fairmount area belong, except for joint fillings, to the Tazewell substage of the Wisconsin stage of glaciation. Eveland (1952) described the following section in the south wall of the Fairmount Quarry:

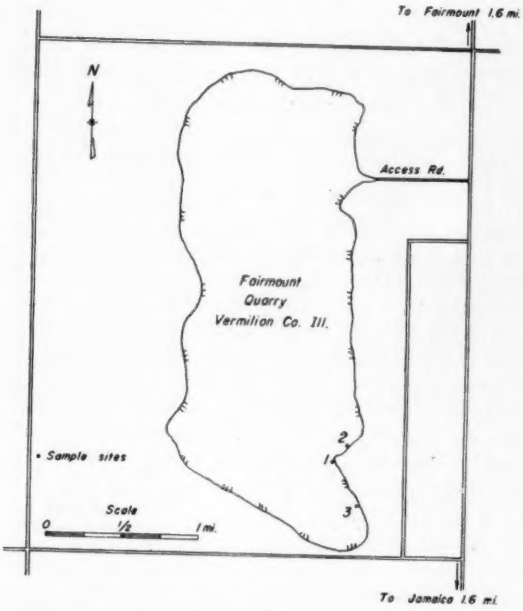
Wisconsin (Tazewell)	
Loess (leached)	1′ 8″
Champaign Till	
Buff, oxidized, leached	1′ 0″
Buff, oxidized, calcareous	8′ 6″
Blue-gray, calcareous	4′ 6″
Pennsylvanian System	
Limestone	

The inner Champaign moraine crosses the northern two-thirds of the quarry, and the south part of the quarry lies within the Champaign drift plain between the middle and inner moraine.

Although the Shelbyville moraine lies some 30 miles farther south, no Shelbyville till is recorded by Eveland; this indicates that he regarded it as lacking because of nondeposition or because of removal prior to deposition of the Champaign till.

Sampling Sites

In April, 1955, blasting operations exposed a new section of the quarry showing several vertical enlarged joints nearly 2 to 3 feet in width and up to about 10 feet deep. The joints were filled with what appeared to



LOCATION MAP

FIG. 1.—Map showing sites from which samples were taken.

FIG. 2.—Filled joints and striations on stripped surface at Site 3.

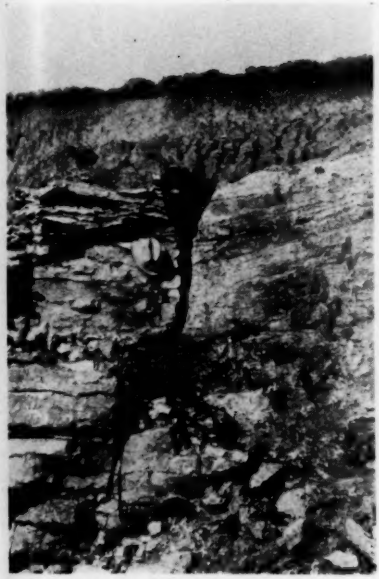


FIG. 3.—Filled joint at Site 1. Pick at contact of Champaign till above and plastic clay below.

be a heterogeneous mixture of gray, red, and purple clay, which closer inspection showed was actually several different types of material—a gray unaltered till containing many cobbles and boulders in the upper part of the joints, a much more plastic brown to purple clay containing weathered pebbles underlying the gray till, and a brown to reddish-brown clay whose relation to the other materials was not clear. The two lower clays were slickensided and squeezed laterally along bedding-planes of the limestone. The authors tentatively concluded that the two lower clays represented, respectively, weathered older till and a pre-glacial joint-filling of limestone residuum.

Unfortunately, it was found on the return to the quarry several months later for mapping and sampling that the face no longer existed and that the joint-fillings earlier exposed had been removed in the quarrying operations. Consequently, other sampling sites were selected. Those selected were two on older faces of the quarry where two rather narrow filled joints were exposed and a third site on the stripped surface at the intersection of two joints. The locations of the three sites are shown in Figure 1.

The enlarged and filled joint which constitutes Sample Site 1 (Figs. 3 and 4) is funnel-shaped, which is typical of joints enlarged by solution. The Champaign till has intruded down about ten inches into the joint.

The joint at Sample Site 2 (Figs. 5 and 6) varies from two to six inches wide. The upper part of the joint at the contact of the limestone with the Champaign till was covered by debris and was not readily available for study. The pebbly clay immediately above the geology pick (Figs. 5 and 6) is interpreted as being a slightly weathered till of pre-Champaign age. The till has been squeezed laterally several inches into the bedding plane. The underlying reddish-brown silty clay is believed to be limestone residuum.

Site 3 (Fig. 2) is located on the stripped surface. The site was investigated by means of a pit 2.5 feet deep. The intersecting joints have widths of 6 and 14 inches. The basal part of the Champaign till is intruded approximately 12 inches into the upper portion of the joint. This unaltered till contains many cobbles and boulders, some of which

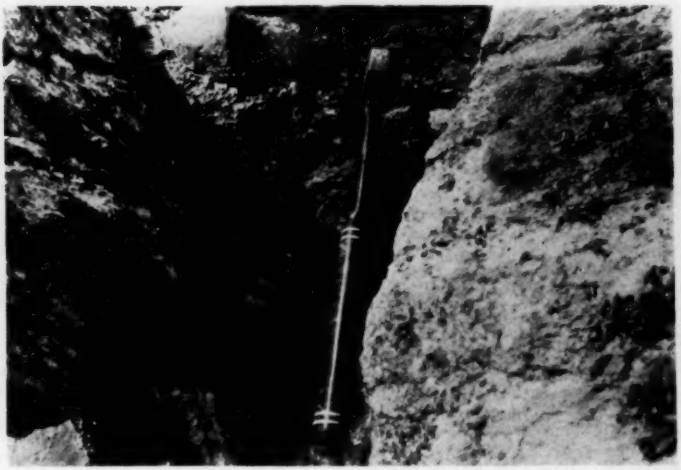


FIG. 4.—Close-up view of filled joint (Site 1). Pick at contact of Champaign till above and plastic clay below.

have been pushed in and their tops planed off and striated parallel to one set of striations on the limestone surface. Beneath the unaltered till is a brown, finely jointed, plastic clay, containing only an occasional small weathered granite or greenstone pebble. This material is tentatively identified as a weathered, older, intruded till.

PLASTICITY CHARACTERISTICS

Correlation of till sheets and sediments in general may be carried out by a number of techniques including grain-size analysis, pebble count, heavy-mineral determination, clay-mineral analysis, or any combination of these. The plasticity characteristics of sediments, rarely used by geologists in their correlation studies, is widely used in the field of soil mechanics. Atterberg (1913) introduced the concept of *liquid limit* and *plastic limit* for agricultural soil classification, and Terzaghi (1925) adapted the concept for use in soil mechanics. The liquid limit is the moisture content of a cohesive sediment just as it passes from the plastic state into a liquid state or slurry, at which point the sediment possesses a slight but measurable shearing strength. Addition of water to a sediment just at the liquid limit forms a slurry. Upon removal of water by drying, the sediment passes into the plastic state. Upon continued drying, the sediment passes through the plastic state to form a stiff semi-brittle material. The moisture content at this change of state is defined as the plastic limit. The liquid and plastic limits of a cohesive sediment are, therefore, the upper and lower limiting moisture contents (expressed as percentages) at which the sediment remains plastic. The numerical dif-

FIG. 5.—Filled joint at Site 2. Pick at contact of gray-brown pebbly clay above and reddish-brown silty clay below.

ference between the liquid and plastic limits is referred to as the *plasticity index* and indicates the range in moisture content over which the sediment is plastic. A large plasticity index of 50 or greater indicates a highly plastic material, while a plasticity index of 20 or less indicates a material possessing only limited plastic qualities.

The procedures for determining the liquid and plastic limits (also referred to as Atterberg limits) are arbitrary but are simple to perform and have been standardized (Casagrande, 1932). The plasticity characteristics of any given sediment are determined chiefly by the grain size of the sediment and mineralogical composition of the clay-size fraction. As both of these properties are accepted by geologists as being of correlative value, it follows that the plasticity characteristics, which are a result of the combined effects, could likewise prove a useful tool in correlation of sediments. Consequently, for the work undertaken in this investigation the plasticity characteristics of the various sediments were determined.

The plasticity characteristics of sediments can best be studied by plotting the liquid limit and plasticity index on a plasticity chart (Fig. 8). The A-line is an empirical boundary between typical clays, which plot above the line, and silts and organic sediments which plot below the line (Casagrande, 1947). The farther to the right along the A-line a particular sediment falls,

FIG. 6.—Close-up view of filled joint (Site 2). Pick at contact of gray-brown pebbly clay above and reddish-brown silty clay below.

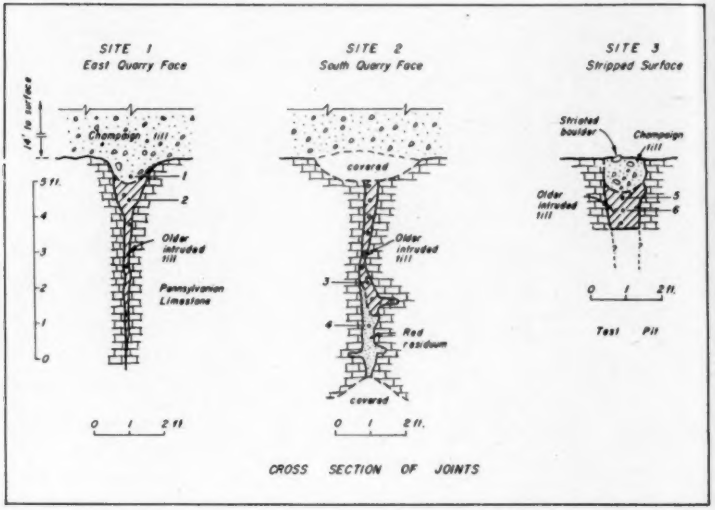


FIG. 7.—Cross-section of joints showing location of samples and type of joint filling.

the greater the plasticity of the sediment.

Sample 1 of unaltered Champaign till from Site 1 is shown plotted at its test values of liquid limit 24.5% and plasticity index of 9.5%. It falls in the zone formed by the plotting of the test results of 13 samples of unweathered till from the Champaign moraine (Larsen and Thornburn, unpubl. rept.). Eighty other samples from unweathered till of the Shelbyville, Cerro Gordo, Le Roy, and West Bloomington moraine also plot in or very near this zone. These data indicate that materials of similar geological origin plot in a small zone essentially parallel to the A-line.

Sample 2 from Site 1 and Sample 3 from Site 2 (Fig. 7) occur in joints beneath the Champaign till. Sample 3 consists of slightly weathered till with scattered, nearly-fresh pebbles of granite and greenstone. It falls within a second cross-hatched zone determined by the plotting of the test results of ten samples from the B-horizon of soils developed on Shelbyville till with little or no loess cover (Thornburn, pers. comm.) in various localities in Shelby, Vermilion, and Montgomery counties. Sample 2 from Site 1 consists of weathered till with only an occasional weathered pebble and plots to the right of Sample 3 along the A-line, indicating a higher plasticity. Although it does not fall within the cross-hatched zone of the weathered Shelbyville samples it is more closely related to this zone than to the others.

Samples 5 and 6 from Site 3 consist of highly weathered, plastic, brown, clay till with an occasional highly weathered pebble. The plotted positions of these samples indi-

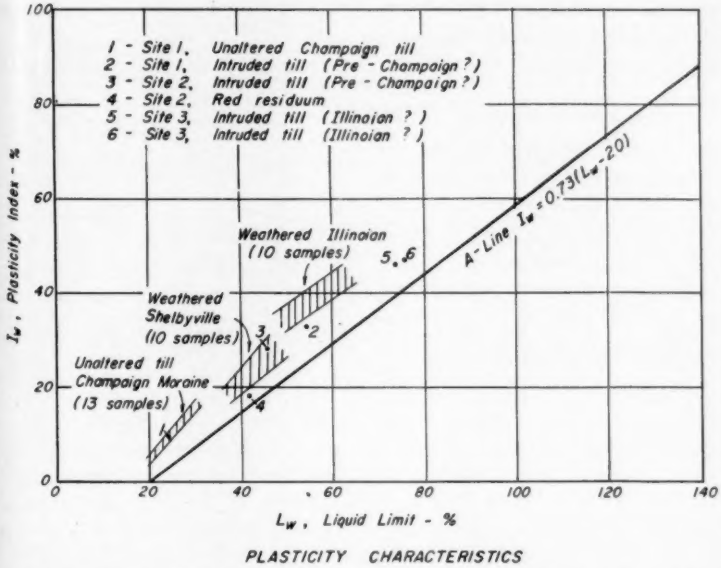

1 - Site 1, Unaltered Champaign till
2 - Site 1, Intruded till (Pre - Champaign ?)
3 - Site 2, Intruded till (Pre - Champaign ?)
4 - Site 2, Red residuum
5 - Site 3, Intruded till (Illinoian ?)
6 - Site 3, Intruded till (Illinoian ?)
Weathered Illinoian (10 samples)
Weathered Shelbyville (10 samples)
Unaltered till Champaign Moraine (13 samples)
A-Line $I_w = 0.73(L_w - 20)$
I_w, Plasticity Index - %
L_w, Liquid Limit - %
PLASTICITY CHARACTERISTICS

FIG. 8.—Standard plasticity-characteristics chart showing plotted positions of plasticity characteristics of samples of material intruded in joints at Fairmount Quarry and their relation to plotted positions of plasticity characteristics of other samples of till in east-central Illinois.

cate they are more plastic than any of the samples studied. They fall close to a third cross-hatched zone which includes the test results of ten samples from the B-horizon of soils developed on Illinoian till with little or no loess cover (Thornburn, pers. comm.) in Crawford, Edwards, Fayette, and Lawrence counties. Samples 5 and 6 might be included in an extended cross-hatched zone of a more thoroughly weathered and more plastic Illinoian till or they may be representatives of a till older than Illinoian.

Sample 4 from Site 2 is regarded as red residuum from the weathering of the bedrock. The point plots close to the A-line and the sample is moderately plastic. This is characteristic of limestone residual soils (Thornburn and Deere, 1955).

SUMMARY

Examination in the field of three filled-joints and laboratory study of the plasticity characteristics of the joint-filling indicate that at least four types of material are present. These are tentatively identified as unaltered Champaign till, slightly weathered pre-Champaign till—possibly Shelbyville—highly weathered till of Illinoian or pre-Illinoian age, and a pre-glacial joint-filling of limestone residuum. The problem will be further studied by observing joints as new faces are opened at the quarry and by studying the plas-

ticity characteristics of the weathered Wisconsin and older tills in the general region.

Acknowledgments

The writers are grateful for the helpful suggestions of George W. White, University of Illinois, and George E. Ekblaw, Illinois State Geological Survey.

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THE SUBSURFACE GLACIAL GEOLOGY AT PROPOSED EFFINGHAM DAMSITE AND ITS ENGINEERING IMPLICATIONS

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For several years the City of Effingham has been concerned with the sufficiency of its municipal water-supply, which is derived from a small lake two miles southwest of the city, in turn maintained by supplemental pumpage from the adjacent Little Wabash River. Investigations of both subsurface groundwater and surface-reservoir possibilities for replacement or additional supplies have been made at various times.

In 1955 Warren and Van Praag, Inc., consulting engineers for the newly created Effingham Water Authority, completed preliminary investigations for a reservoir in the valley of Blue Point Creek with a damsite in the SE. ¼ sec. 22, T. 8 N., R. 5 E., about 4 miles west of Effingham (Fig. 1).

In general the geologic materials in the region consist of a downward succession of: 1) a thin mantle of loessial silt of Wisconsin age, in which the surficial topsoil has been principally developed; 2) an irregular layer of sand and gravel of Illinoian age, of which at least the upper part has been more or less weathered and consequently is more or less clayey; 3) an irregular deposit of clay till of Illinoian age; 4) another irregular layer of clay till of Kansan age, of which the upper part was weathered during the Yarmouth interglacial stage preceding the advent of the Illinoian glacier; and 5) bedrock formations belonging to the Pennsylvanian system. Silty sand and gravel, in part deposited directly from the Illinoian glacier and in part deposited by present streams reworking the Illinoian outwash, occur in the bottoms of the principal valleys.

Before making their studies the engineers had informed themselves about the geologic conditions and were aware that the Illinoian sand and gravel deposits, somewhat unusual in Illinoian drift, required special attention. Consequently they included in their investigations an adequate program of test-boring at the damsite and obtained good sets of samples which were referred to us for identification and interpretation.

As shown on the accompanying diagrammatic cross-section (Fig. 2) the materials encountered in the test-borings are in accord with and generally confirm the regional sequence. The Wisconsin loess is represented by noncalcareous silty soil in the top 4 to 5 feet of borings 9 and 10. (Boring 10, not shown on diagram, is in spillway section to left of diagram.) The original Illinoian upland outwash, now noncalcareous, is represented in the

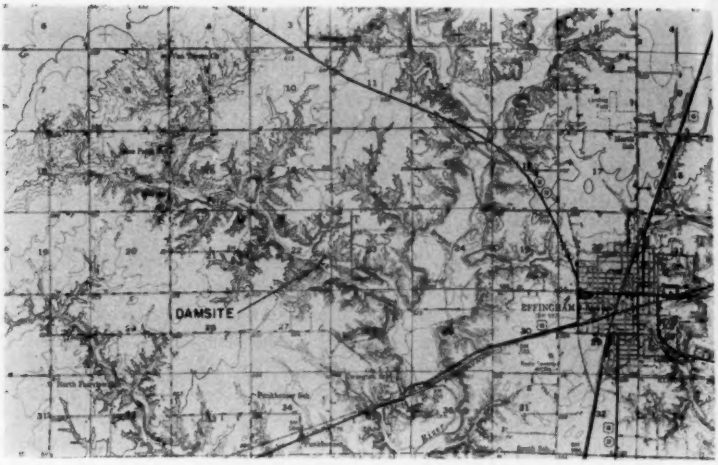

FIG. 1.—Location of proposed damsite on central part of Effingham quadrangle topographic map.

same borings, down to depths of 15 and 17 feet, respectively. The reworked (?) Illinoian outwash in the valley extends practically from the surface down to depths of 11 feet in boring 1, 21 feet in boring 6, 30 feet in boring 2, 13 feet in boring 7, 8 feet in boring 3, and 4.5 feet in boring 4 but is absent in boring 8. It is probably mantled by alluvial silt, but no such material appears in any sample. It is noncalcareous except for the bottom eight feet in boring 2 and is oxidized throughout.

Illinoian till occurs between depths of 0 and 52 feet in boring 5, 11 and 19 feet in boring 1, 19 and 21 feet in boring 7, 4.5 and 6 feet in boring 4, 0 and 15 feet in boring 8, 15 and 22 feet in boring 9, and 17 and 22 feet in boring 10 but is absent in borings 2, 3 and 6. The upper nine feet of the till in boring 5 is leached, but all the rest is calcareous. It is oxidized to a depth of more than 8 feet in boring 8, more than 12 feet in borings 1 and 5, and more than 16 feet in borings 9 and 10. It is not oxidized in boring 7, at a depth of 19 feet. In boring 7 the Illinoian till is overlain by six feet of faintly laminated fine-grained silt (B in Fig. 2) which is also probably of Illinoian or immediate post-Illinoian age, as it is in turn overlain by the reworked (?) sand and gravel.

Pro-Illinoian Loveland loess is represented by 6 inches of gray calcareous silt between depths of 19 and 19.5 feet in boring 1 and one foot of light-tan, noncalcareous silt between depths of 21 and 22 feet in boring 6 (C in Fig. 2). Because boring 6 was stopped at 22 feet it did not reveal the thickness of the Loveland loess at that spot.

Kansan till occurs at depths of 19.5 feet in boring 1, 21 feet in boring 7, 12 feet in boring 3, 6 feet in boring 4, and 15 feet in boring 8. It is absent in boring 2, but is prob-

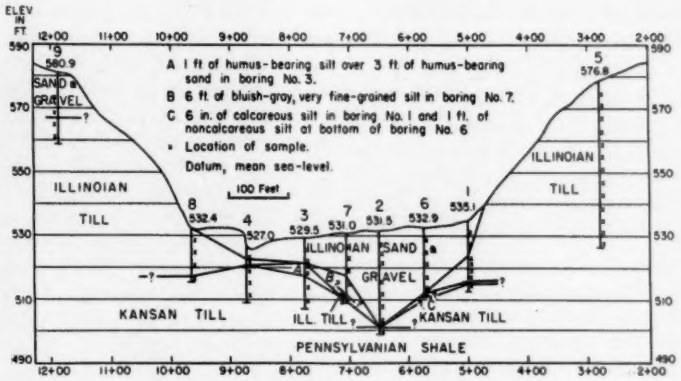

FIG. 2.—Diagrammatic cross-section of geologic materials at proposed Effingham damsite, based on samples from test-borings.

ably not far below the bottom depth of 22 feet in boring 6, and is doubtless present at undetermined depths under borings 5, 9, and 10. The top surface of the Kansan till is irregular, due to weathering and erosion during the Yarmouth interglacial stage, and all of the till represented in the samples is noncalcareous and brown or greenish. The greenish color occurs in borings 1 and 7, in which the top of the till is lower than in borings 3, 4, and 8, and may indicate the presence of a Yarmouth valley. The humus-bearing silt and sand between depths of 8 and 12 feet in boring 3 (A in Fig. 2) are probably alluvial deposits of Yarmouth age.

Formations of Pennsylvanian age underlie the entire area, but only boring 2 was drilled deep enough to encounter weathered shale of this age.

Practically all of the material represented by the samples will provide satisfactory foundation for the dam. The humus-bearing material between depths of 8 and 12 feet in boring 3 is so sandy and gravelly and contains so little humus that its bearing-power is not seriously affected. The only material that may have relatively low bearing-power is the silt between depths 13 and 19 feet in boring 7, but as it is not recorded in the adjacent borings it appears to be so localized that it can be disregarded unless for some reason the material over it is excavated.

However, the reworked (?) Illinoian sand and gravel in the valley is sufficiently permeable that considerable and possibly dangerous leakage under the dam may occur unless adequate preventive measures, such as sheet-piling, are incorporated in the design of the dam. The sheet-piling should be driven through both the humus-bearing material in boring 3 and the silt in boring 7, to the underlying till. Because sheet-piling is not always wholly effective, there should probably also be incorporated in the dam design an adequate drainage section in the downstream toe of the dam, and, for safety's sake, it would be desirable

to install piezometers in this drainage section.

The outwash sand and gravel on the uplands is also permeable, and thus, unless there is some way of cutting it off, the dam should probably be constructed so that the water-level in the reservoir is little if any above the bottom of the outwash.

The effects of this layer of outwash must also be considered in designing the spillway that will be cut through it. Possibly potential seepage can be cut off by sheet-piling, but this may build up excessive hydraulic pressures on the bottom and sides of the spillway, and consequently it may be preferable to install drains under and along the sides of the spillway where it cuts through the outwash and to discharge these drains into the spillway itself.

One of the most serious problems that seems to be present is an adequate source of satisfactory material for the dam. As the upper material on the uplands is principally silt, sand, and gravel, it is hardly suitable material for a dam, except for a drainage section in the downstream part. It can be used in the main section of the dam only if it is mixed with an adequate amount of clay, and this will require careful measurements of the proper compaction of such a mixture. This precaution will have to be carefully exercised if it is planned to use in the dam the material excavated from the spillway. The only source of clay is the till underlying the sand and gravel. Inasmuch as the till is satisfactory material for the dam, it may be desirable to plan to obtain the material for the dam from excavations in the till in the lower parts of the valley-walls upstream from the dam. Such excavation would also increase the capacity of the reservoir.

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A PSEUDO-RING DIKE, MT. DESERT ISLAND, MAINE

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Mount Desert Island, Maine, the largest bedrock island on our Atlantic coast, is underlain by a central mass of granite (probably late Devonian) which is surrounded by a nearly continuous fringe of older rock (Fig. 1). The older rock consists mostly of contact-metamorphosed quartzite and siliceous sediments of Silurian (?) age, much altered gabbros of possibly Upper Devonian age, and some schist, gneiss, and quartzite of the Bartlett Island formation (possibly Lower Cambrian).

The granite core of the island is now known to consist of two distinct rock units. The larger and older is a coarse-grained hornblende granite. The younger is a medium- to fine-grained biotite granite which forms a discrete body cutting out much of the northwestern portion of the hornblende granite. A number of smaller masses of hornblende granite occur in the older fringe rock of the island and some of the neighboring islands to the west (Fig. 1). These are believed to be ring dikes and, although somewhat variable in width, they can be traced for several miles. Where the ring dikes terminate, shatter zones appear to continue for several miles through the older rock.

It has already been shown (Chapman, C. A., 1953) that the two large granite masses of the island have been emplaced by cauldron subsidence. The best evidence for such subsidence is as follows: 1) smooth rounded contacts resemble those in most other areas of cauldron subsidence; 2) centripetal pattern of dips of the planar structures in the older fringe rocks; 3) contact shatter-zone around the granite; 4) abundant steep tangential pegmatite veins in the surrounding breccia zone; and 5) numerous tangential granite satellites or ring dikes in the fringe rock.

In the northeastern part of the hornblende granite area (Fig. 1), extending northward along the western slopes of McFarland and Youngs mountains (Fig. 2), is a crescent-shaped mass of granite "porphyry". The mass is about 1.5 miles long in a north-south direction and 0.2 miles wide. The crescent is concave to the west with a radius of curvature of approximately 1.5 miles. This crescent subtends an angle of about 130 degrees, and either cusp terminates the form rather bluntly.

In the field, contacts between the "porphyry" and enclosing hornblende granite are not sharp. On the other hand they are not of a simple gradational character, with typical "porphyry" gradually passing over into hornblende granite. Instead, these two geologic units are separated by a highly irregular and ill-defined boundary zone in which both rock types appear mixed to a greater or less degree. Patches of

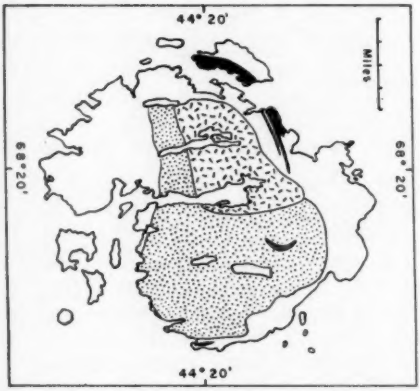

FIG. 1.—Simplified geologic map of Mt. Desert Island, Maine. Biotite granite, dashed; hornblende granite, stippled; country rock, blank; granite "porphyry", lined; ring dikes, black. The four elongate blank areas within the granite area are freshwater lakes.

hornblende granite up to a few hundred feet across occur locally as much as a few hundred feet in from this boundary zone. These large inclusion-like masses of hornblende granite are as vaguely separated from the surrounding "porphyry" as is the "porphyry" from its enclosing hornblende granite.

The hornblende granite is a pink, coarse-grained rock of very uniform character. It is allotriomorphic granular and composed predominantly of microperthite as grains 3 to 8 mm. across and commonly showing a poorly developed zoning. Quartz as slightly smaller grains is commonly intergrown with perthite to form implication texture. Patches several millimeters across of fine-grained feldspar and deep green to yellow-brown hornblende are commonly observed. Hornblende also occurs outside these patches as large euhedral to irregular grains. A little biotite, magnetite, apatite, and well-formed zircon crystals constitute the accessories.

The "porphyry" is a pink rock with abundant quartz and feldspar crystals about 5 mm. across in a fine-grained matrix. In many specimens patches of "porphyry" are intimately associated with patches of hornblende granite, and contacts between rock types are vaguely defined. Thin sections show rather wide ranges in texture. At one extreme, numerous "phenocrysts" of quartz and microperthite appear embedded in a fine-grained mixture of microperthite, quartz, and mafics. At the other extreme, the rock resembles the hornblende granite with but a small amount of fine-grained intergranular material.

In the typical "porphyry", large grains of quartz (about 5 mm. across) are abundant. These show clear centers, but peripheral zones (1 mm. wide) are filled with diversely oriented, tiny grains of perthite (Fig. 3). Superficially the clear cores appear as phenocrysts in a fine matrix of quartz and feldspar; but, under crossed nicols and more strikingly so with the gypsum plate inserted, the quartz of the apparent matrix is in optical continuity with the clear cores. The line of demarkation between core and feldspar-rich fringe is generally sharp, and round to subpolygonal. Where quartz grains are smaller, quartz cores are correspondingly smaller. In the smallest quartz grains no core is observed and the entire crystal is crowded with tiny feldspar grains. Apparently, therefore, cores occur only in those quartz grains whose diameter exceeds about 2 mm.

Large feldspar grains uncommonly appear as isolated crystals except in those specimens with abundant matrix. Most commonly they occur in aggregates with more or less quartz and hornblende. These aggregates appear as patches of the hornblende granite and are penetrated and transected by numerous irregular veins of medium- to fine-grained quartz which poikilitically encloses abundant tiny feldspar grains. Where veins are extensively developed, large feldspar crystals are isolated in a finer matrix and resemble phenocrysts.

The crescentic shape and "porphyritic" texture of McFarland Mountain body suggest the mass is a ring dike emplaced in the slightly older hornblende granite. This idea is further substantiated by the facts, already stated, that there are several ring dikes on and adjacent to Mount Desert Island, and that the hornblende granite and biotite granite themselves have been emplaced by cauldron subsidence. The crescent shape of this "porphyry" mass resembles that of several ring dikes in New Hampshire (Billings, 1955).

Most field and microscopic evidence, however, is strong against interpreting the "porphyry" mass as a ring dike. The lack of a sharp contact with chill effects, of well-defined inclusions, and of apophyses strongly opposes the magmatic interpretation. Microscopically the rock is not a true porphyry. The "phenocrysts" of quartz and feldspar represent relict crystals or crystal aggregates from the coarse-grained hornblende granite between which reconstitution of material has occurred. Most of the textures and structures of the hornblende granite

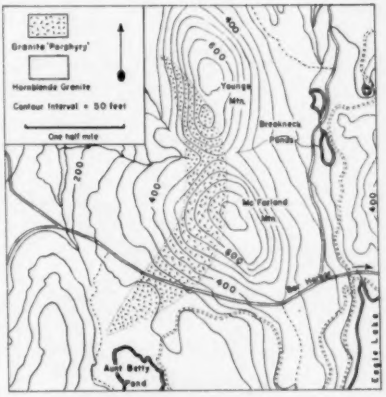

FIG. 2.—McFarland Mountain pseudo-ring dike.

are partially preserved in the "porphyry", and all stages in the apparent disintegration of the hornblende granite may be observed.

The "porphyry" is believed to be derived from the hornblende granite by intergranular recrystallization. This process of recrystallization appears to have been confined to a shatter-zone or zone of ring-fracturing associated with local subsidence in the hornblende granite. This belief is supported by the fact that several arcuate shatter-zones associated with ring dikes are found in the older fringe rock on the western side of the island. The association of ring dike with shatter-zone has been well demonstrated in the Mount Washington, New Hampshire Quadrangle (Chapman, R. W., 1942), where a shatter-zone (0.2-mile wide) trends in arcuate fashion for about five miles. At one end it passes into a ring dike which extends beyond for a distance of about two miles. The absence of an associated ring dike in the McFarland Mountain

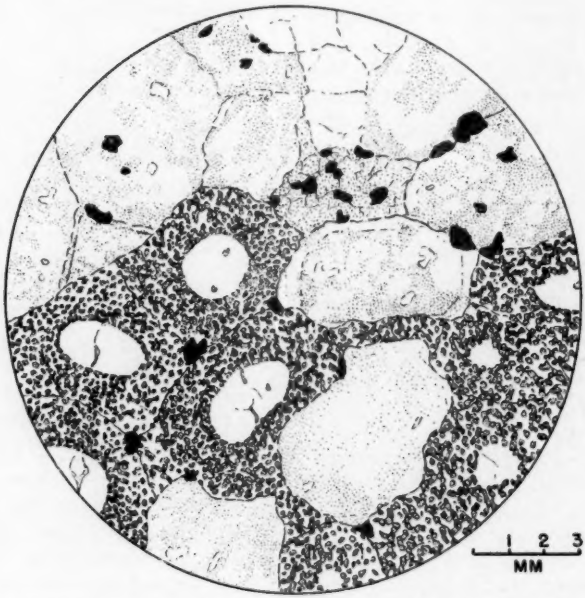

FIG. 3.—Granite "porphyry". Quartz, clear; microperthite, stippled; hornblende and magnetite, dark.

area may be the result of inadequate dilation of the shatter-zone and/or the nonavailability of magma.

There is good reason to believe, therefore, that a ring-fracture zone, approximately three miles in diameter, formed in the hornblende granite. It seems likely that, at our present level of observation, at least, the zone of dislocation did not form a complete ring, but shattering was most pronounced and extensive along the eastern portion of the subsiding granite block. Such a mechanism not only explains the crescent shape of the body with its convex side to the east, but provides the necessary physical conditions for intergranular recrystallization. "Porphyry" formation may have been enhanced by fluids which had their origin in depth and moved along fractures of the shatter zone. The porphyry body, therefore, is not a true-ring dike and may be called a pseudo-ring dike. It was dependent for its formation, however, upon the mechanics of ring fracturing and cauldron subsidence.

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BIOCALCARENITES IN SOME UPPER PENNSYLVANIAN LIMESTONES IN ILLINOIS

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Most Pennsylvanian limestones of Illinois are fine grained and, though they contain fossils, their general character suggests that they were deposited primarily as calcareous muds. During an economic study of the Pennsylvanian limestones in 37 commercial quarries of the state, the occurrence of a biocalcarenite at or near the top of the LaSalle, Livingston, and Millersville limestones was noted at a number of places. Each of these limestones has at one time been considered equivalent to one or both of the others (Dunbar and Henbest, 1942; Lamar and Willman, 1934; Newton, 1941; Wanless, 1955; Potter, 1956). A similar stratum also was observed near the top of a few other Pennsylvanian limestones but was not as commonly present or as widespread as the biocalcarenites previously mentioned.

The results of an investigation covering the nature and abundance of the clastic materials in the LaSalle, Livingston, and Millersville calcarenites and an interpretation of their significance in terms of sedimentation conditions and in relation to correlation of the limestones are presented herein.

Locations of the quarries in which the biocalcarenites of these limestones were observed and sampled and of four drill cores in the Millersville limestone from which the calcarenite was sampled, are shown in Figure 1 and listed in Table 1.

Occurrence of Calcarenite

The biocalcarenite at the top of the LaSalle, Livingston, and Millersville limestones is from 6 inches to about 7 feet thick. It is part of an upper limestone unit 6 to 14 feet thick and characterizes the three limestones at many places. The variation in the thickness of the calcarenite bed may be attributed, at least in part, to erosion. Calcarenite was found in each of the four Millersville cores examined and sampled.

Character of Calcarenites

The nature of the calcarenites was investigated by study of thin sections (Fig. 2) and rock slices from each limestone sample cut at right angles to the bedding. The slices were etched with hydrochloric or acetic acid to facilitate study. A binocular microscope was used to estimate the percentage of detritus, its size, range, and average size. The percentage by number of each of the five principal types of clastic material also was determined.

Results given in Table 1 and Figure 3 indicate that the detritus is principally crinoid fragments, shell fragments, foraminifera, oolites, and bryozoan fragments. The matrix of

TABLE 1.—Localities and Size and Percentage of Detritus.

Locality near	Township	Range	Section	¼	¼	Percentage detritus	Size (mm.)	
							Range	Average
		LaSalle limestone						
LaSalle	33N	1E	14	NE	SE	82	0.5-3.0	0.9
Oglesby	32N	2E	6	NE	SW	80	0.1-4.0	1.0
Oglesby	32N	2E	6	NW	SE	80	0.5-4.0	1.0
Pontiac	28N	5E	9	NW	SE	75	0.5-4.0	1.1
					Av.	79	0.1-4.0	1.0
		Livingston limestone						
Casey	10N	14W	4	SE	SE	84	0.1-5.0	1.0
Fairmount	18N	13W	21	SW	SW	75	0.2-5.0	1.2
West Union	9N	11W	29	NW	SW	78	0.1-8.0	1.0
					Av.	79	0.1-8.0	1.1
		Millersville limestone						
Arthur	15N	6E	12	SE	SE	73	0.1-5.0	1.0
Arthur	15N	6E	15	SE	SE	76	0.5-7.0	1.1
Pana	11N	1E	33	NE	NW	82	0.05-3.0	1.2
Ramsey	8N	1E	19	NE	SE	72	0.5-3.0	1.0
Tuscola	16N	7E	36	SW	SE	76	0.1-4.0	1.0
					Av.	76	0.05-7.0	1.1

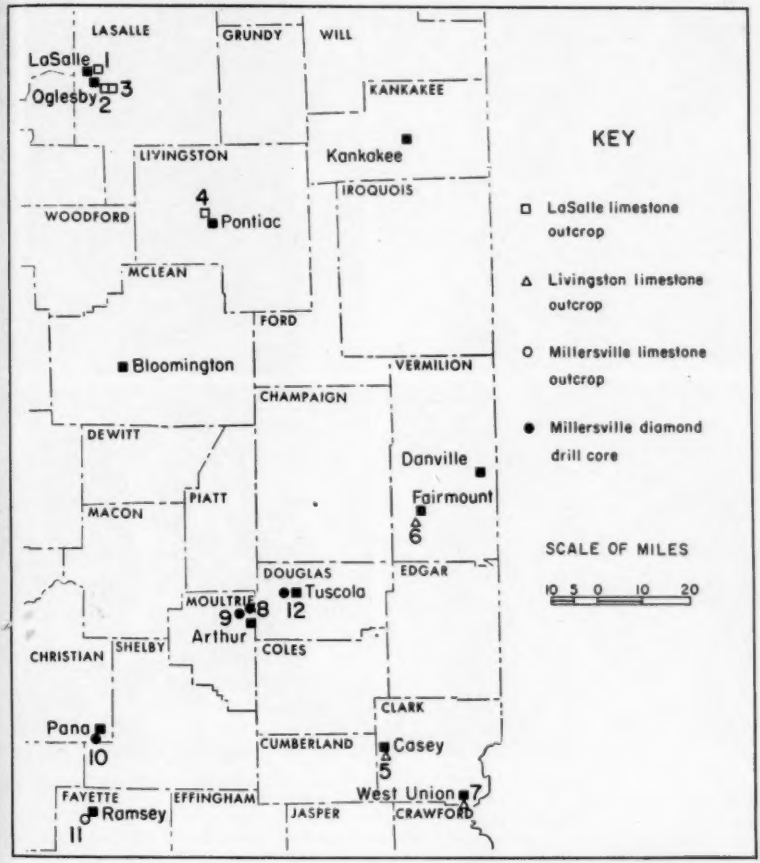

FIG. 1.—Limestone formations sampled and sources of samples.

the calcarenites was not investigated in detail, but it is calcite with a small-to-moderate amount of silt-size quartz in some samples.

The calcareous clastic material comprises 73 to 84% of the samples. Of the five major types of clastic particles, fragments of crinoids and crinoid stems are commonly most abundant, followed in order by shell fragments, foraminifera, oolites, and bryozoa. Average size of the clastic particles is consistently about one millimeter.

Averages for the content of clastic materials according to limestone formations are given in Figure 3. The LaSalle and Livingston calcarenites contain a greater percentage of crinoid fragments than does the Millersville calcarenite. The range in the percentage of shell fragments

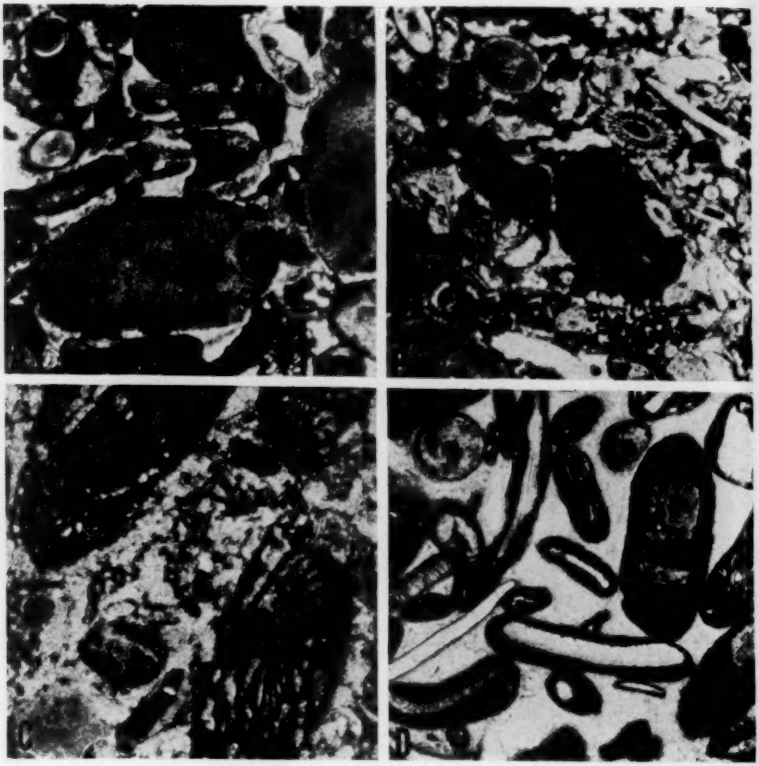

FIG. 2.—Thin sections of biocalcarenites: *A*. crinoid stems and oolites in LaSalle limestone, 9 X; *B*. algal masses, center, and crinoid fragments in Livingston limestone, 9 X; *C*. foraminifera in Millersville limestone, 9 X; *D*. Millersville calcarenite at Ramsey showing elongate nature of particles and dark accreted calcite around grain centers, 6 X.

in the LaSalle and Millersville calcarenites is greater than that in the Livingston, but the average amount of shell fragments is not greatly different. The content of foraminifera in the LaSalle and Livingston calcarenites is strikingly similar; the Millersville shows a greater range in foraminiferan content, and the average content is higher. The average percentage of oolites is similar for the three limestones, as is the range in number of oolites present. However, the Millersville and Livingston calcarenites generally contain more oolites than the LaSalle. The bryozoan content of all three limestones is low, especially so in the LaSalle calcarenite.

To summarize, the LaSalle and Livingston limestones are roughly similar in content of crinoid fragments, shell fragments, and foraminifera, whereas the Livingston

SAMPLE NO. AND LOCATION	CRINOID FRAGMENTS % 10 30 50 70 90	SHELL FRAGMENTS % 10 20 30 40 50	FORAMINIFERA % 0 20 40 60	OOLITES % 0 4 8 12 16	BRYOZOA FRGMTS % 0 2 4 6 8
	LA SALLE LIMESTONE				
1. LA SALLE	o	o	o	o	o
2. OGLESBY	o	o	o	o	o
3. OGLESBY	o	o	o	o	o
4. PONTIAC	o	o	o	o	o
Average	●	●	●	●	●
	LIVINGSTON LIMESTONE				
5. CASEY	o	o	o	o	o
6. FAIRMOUNT	o	o	o	o	o
7. W. UNION	o	o	o	o	o
Average	●	●	●	●	●
	MILLERSVILLE LIMESTONE				
8. ARTHUR*	o	o	o	o	o
9. ARTHUR*	o	o	o	o	o
10. PANA*	o	o	o	o	o
11. RAMSEY	o	o	o	o	o
12. TUSCOLA*	o	o	o	o	o
Average	●	●	●	●	●

* Diamond drill core samples

FIG. 3.—Composition of biocalcarenite in percentage by number of clastic particles present.

and Millersville limestones show kinship in number of oolites and bryozoan fragments. Data of this type probably are not an adequate basis for establishing correlations of beds. Insofar as they may be significant in this regard, they would seem to confirm an interrelationship previously suggested by study of the stratigraphic succession, among the three limestones, and to demonstrate a general similarity of the clastic materials in the sea in which the limestones were deposited.

The Millersville calcarenite in the quarry near Ramsey (Fig. 2D) and in the two cores near Arthur is unusual in that many of the fossil fragments are elongate, well rounded, and covered by a coating of carbonate material. It was not possible to establish definitely the origin of this coating, but it is believed to be either algal (Johnson, 1954) or to represent a layer of lime mud accreted to the fossil fragments as they were rolled about on a sea floor or tidal flat. It is also conceivable that the coating may represent the first stage of oolite formation.

SEDIMENTATIONAL SIGNIFICANCE OF CALCARENITES

Those parts of the LaSalle, Livingston, and Millersville limestones below the calcarenite zone generally consist of two or three fine-grained limestone units separated by micaceous gray or black shale. Such deposits most likely were formed by an alternation of relatively deep- and shallow-water conditions involving chemical precipitates on the one hand and the deposition of fine clastic sediments on the other. The calcarenite indicates a change to a different type of deposition during the closing stages of formation of the last of the three limestone units, namely, the deposition of relatively coarse clastics of essentially local derivation composed of fossil detri-

tus and oolites. Crinoids, bryozoa, brachiopods, and foraminifera were abundant in the sea, and sand-size materials became the major type of sediment for the first time during the history of the limestones. It appears likely that the phenomena described accompanied a temporary regressive shallowing of the sea, which was terminated by a readvance that deposited the shales above the LaSalle, Livingston, and Millersville limestones.

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PHYSICS

TRANSMITTING MOTION THROUGH THE WALLS OF SEALED VESSELS

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Micro Switch, Freeport

Introduction

Transmitting of motion through the walls of sealed vessels is a frequent requirement in laboratories and on industrial equipment. Use of magnetic influence through vessel walls to produce motion inside avoids the problems of maintaining hermetic seal and has the advantage of producing zero effect on internal volume. This method, however, is of limited usefulness.

Practically the same result is accomplished with a glass enclosure in which an inwardly extending, bellows-like portion resiliently supports a glass rod (Fig. 1). The support is sufficiently flexible to permit lever-like motion of the rod, which motion closes and opens electrical contacts with repeatable precision; that is, make and break of contact always occurs at the same position of the glass rod. High vacuum affords desirable contact functioning.

Sealed Switches Required on Aircraft

Because of its fragility, this unit is unsuited to many uses, such as on aircraft. The requirement there is for ruggedness as well as dependability. Switches must be sealed to prevent formation of frost on contacts as planes rapidly descend into damp, sea-level atmosphere after long exposure to the low pressure and extreme cold of high altitude. Operation of unsealed contacts in a test chamber, where pressure changes simulate ascent to 100,000 feet of altitude, shows that under such conditions arcing time increases and the switch may fail to open circuit.

This problem was first met by use of pressurized gas in a truly hermetic enclosure, shown diagrammatically in Figure 2. Motion is transmitted by a C-shaped yoke supported at its closed end by a "Wobblefram". Force and motion transmitted by this yoke are substantially unaffected by rise or fall of the "Wobblefram" due to changes in ambient pressure. Also, internal volume is substantially unaffected by the limited oscillating motion of operation. Flexible connections between the glass-bead-supported electrical terminals and the external wiring connectors protect the glass beads from damage by stresses. This unit was originally designed to be interchangeable with previously unsealed units (Fig. 3, A).

Requirements of the aircraft industry for reduction in size and weight led to design of the unit shown in Figure 3, B. Here, mo-

FIG. 1.—Glass-enclosed, evacuated, electric switch. Contacts moved by glass rod which pivots on bellows-like portion of envelope.

tion is transmitted to a subminiature snap-acting switch by a simple silicone diaphragm bonded between the reciprocating metal plunger and the aluminum housing. The small diameter of this diaphragm avoids serious effect on operating characteristics by altitude pressure changes. The thin aluminum shell is filled with epoxy resin which provides a satisfactory seal, combined with excellent electrical insulation. Electrical connections are brought out through flexible leads.

A New Sealing Method

These methods for sealing switch enclosures and transmitting limited, reciprocating motion solved only part of the altitude-switching problems, for spring - return operating mechanisms are also vulnerable to freezing but require greater motion than is afforded by diaphragms of any type. The need for transmitting unlimited rotary, as well as greater reciprocating, motion is met by a new method (Fig. 4). A silicone O-ring seals the stainless steel shaft through a stainless steel stem with a teflon scraper at the outer end of the stem to exclude dirt and to scrape ice from the shaft. This scraper is both self-lubricating and inert to oils, solvents, and other materials which might damage O-rings.

In Figure 4, the sealed stem is shown as solder-sealed to the housing of a plunger-actuated, double-pole, double-throw electric switch with terminals brought out through glass beads, fused between housing and electrodes. Silicone-insulated, lead wires are soldered to terminals. Insulation between the closely spaced joints and firm anchoring of the leads are provided by filling the terminal cap with epoxy resin. A return spring is built into the stem, and excursion of the plunger is limited to less than the distance between O-ring and teflon scraper. Thus, the perfection of seal between plunger and O-ring is protected against dust, damaging liquids, and mechanical roughening of the plunger surface.

Figure 5 shows the use of this type of seal on a relatively large piece of equipment. This unit is used in testing circuits prior to the release of guided missiles by the simultaneous operation of 72 electric switches. The seal must be such as to insure reliable functioning when exposed to the heat and sand of deserts, the cold and ice of the arctics, ocean spray, oils, or aromatic fuels.

Departure from the use of truly hermetic construction (fused joints

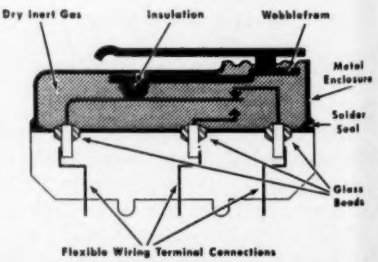

FIG. 2.—Schematic sketch of switch operated by "Wobblefram" action.

only) could be considered as acceptable only after the mass-spectrometer leak detector became available as a practical production tool. The method is first to pump the switch enclosure to a few hundredths of a micron of mercury pressure. When the pressure is down, a valve is moved which connects the mass spectrometer to the vacuum manifold. Helium is sprayed over the switch, and, if there is a leak large enough to fill a teaspoon with gas in 100 years, a howling sound gives warning and the instrument gives indication.

Seals Pass Severe Tests

Standardized seals of this type have been used on switches which have passed Military Standard tests. These tests include continuous operation during exposure to temperatures from +150° to −30° C. with shock change between those limits and with external pressures varying from 760 mm. to 100 microns. There are hours of exposure to a stream of sand and dust, and operation under a head of 36 inches of water, with rapid changes in temperature from +65° to +1° C. The nonwetting characteristic of teflon makes it possible for return springs to break instantly ⅛ inch of clear ice which has been held at −65° C. for 3 hours. No seal has ever developed a leak under any of these tests, as determined by the mass spectrometer.

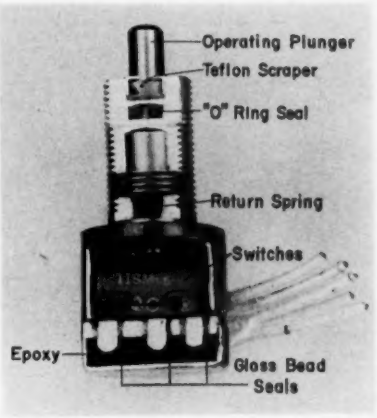

Fig. 4.—Cut-away section of sealed stem and double-pole, doublethrow, aircraft switch.

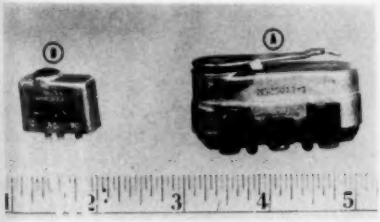

Fig. 3—*A*. Metal-jacketed, hermetically sealed, snap-acting switch. Operated by flexing "Wobblefram"; *B*. subminiature switch sealed within block of epoxy resin and operated through small-diameter diaphragm.

Design is Simple — Production Requirements Rigid

Quantity production of seals which pass these tests is made possible by the simplicity of design. There is the further requirement, however, that materials and finishes be of the needed quality. The specially hardened, stainless steel shafts are polished to a permissible deviation from perfection no greater than six-millionths of an inch. O-rings are triply inspected for surface condition. Lubricant must not flow at 150° C. nor stiffen at −80° C.

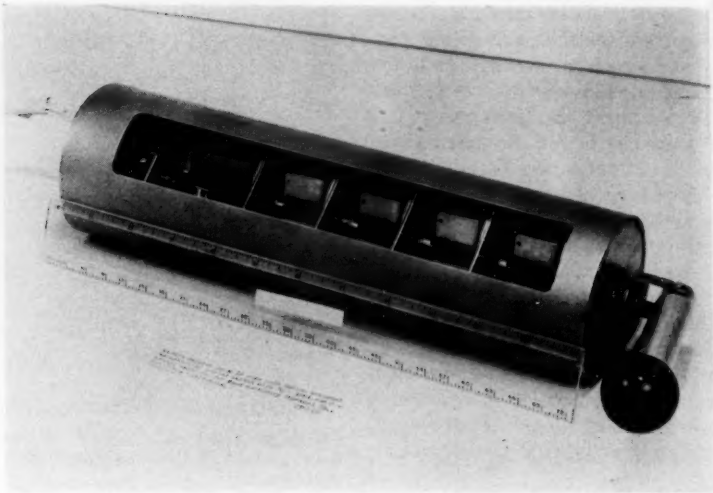

FIG. 5.—Sealed operating stem and cut-open housing for 70 subminature and 2 heavy duty switches, simultaneously operated for testing of guided-missile, launching circuits.

By meeting these standards the seal between relatively moving surfaces is as perfect as if the surfaces were fused together.

SUMMARY

Simplicity of construction characterizes this new and widely useful method for transmitting unlimited rotary motion and substantial linear motion through the walls of vessels with the equivalent of hermetic sealing. Reliability of performance is accomplished by the use of suitably finished materials which are inert to ambient conditions. Lubricant must remain effective over the range of temperature exposure. Standardized sealed stems, which may include overtravel action and return springs, are readily attached to any desired enclosure and may also act as mounting means.

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ACOUSTIC PROBLEMS OF THE FLUTE

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The purpose of this paper is twofold: 1) to describe a physical problem which, though apparently simple and straightforward, has not been entirely solved after extensive investigation; and 2) to describe some of the phenomena observed and some methods used to study them. It has more than purely academic interest, since such methods are useful in many other kinds of work.

Historical Background

Musical instruments of the flute family (including the syrinx or panpipe, the Egyptian nay, etc.) are at least as old as our written history; instruments are extant which have been dated as early as 2700 B. C. Many of these were sounded with a reed mouthpiece and some with an embouchure hole in the side, as in the modern flute, or in the end, as in the nay or the shepherd's pipe.

The modern cylindrical flute is almost unique among orchestral instruments in that it is the direct outcome of an intensive investigation begun by Theobald Boehm a century and a quarter ago. He hoped to design an instrument which would be perfect acoustically, making no compromise with the necessities of mechanism. In a detailed study of the construction and characteristics of the instrument, he made and tested more than 300 flutes. His success may be judged from the fact that the Boehm flute of today is dimensionally practically identical with the specifications he set up a century ago, and, as C. Max Champion says (Grove, 1954: 176), "It is not likely that the flute can be further improved, and it remains today a monument to its designer."

Formation of the Musical Tone

In most wind instruments, the source of sound is a mechanical reed, composed of thin, flexible strips of cane or the lips of the player. The principal function of the tube is that of a resonator, strongly reenforcing certain components of the comparatively random sound produced by the reed and thus causing the instrument to sound a tone of a single predominant frequency.

The flute employs no mechanical reed. Instead, a thin jet of air at a high velocity is directed at the edge of the embouchure hole, producing pulses or disturbances having random frequencies over a considerable range. The tube of the flute, with its length adjusted by the opening of certain holes, resonates at and strongly reenforces the desired tone. Through "embouchure adjustment", or the control of size, velocity and direction of the jet of air, the player produces the fundamental (the lowest octave) or the second, third, or even fourth harmonic frequency.

The flue-type organ pipe is customarily used for demonstration of this phenomenon. The textbook descriptions usually point out that: 1) for an open pipe, the wave-length of the note produced is equal to twice the length of the pipe; 2) for a closed pipe, the wave-length is four times the length of the pipe; 3) all tones produced by either open or closed pipe are harmonically related; and 4) that there is always an anti-node or loop at the open end and at the mouth, and one or more nodes distributed at equal intervals along the pipe. This is, however, only an approximation of the behavior of an actual pipe—for many pipes a very rough approximation.

So early a worker as Savart (1823) located the nodes in a speaking organ-pipe by lowering within it a tambourine sprinkled with sand, demonstrating that they were not symmetrically placed with reference to the ends of the tube, and that there was an end-effect (perhaps better described as a diameter-effect). Later workers, including Helmholtz (1885) and Rayleigh (Strutt, 1896) described these phenomena in some detail, giving correction-values of 0.6 times the radius for a straight tube, and 0.82 R for a flanged tube. Most of the early workers considered that the end-effect did not depend upon frequency, but more precise experiments by later workers tend to disprove this.

Organ-builders, in general, seem to hold somewhat different opinions on the subject than physicists or mathematicians. Cavaille-Coll (1860), for example, employed a factor of 1.66 instead of 0.6, and Smith (1911) recommended a factor of 1.0 for some pipes and 2.0 for others. These factors, however, contain an allowance for the partially open upper end of the pipe. The criterion of the organ-builder is "this is the way it sounds best," and this criterion justifiably takes precedence over academic arguments.

The phenomenon of "speaking" causes, in some manner not entirely explained, a further change in the effective length of the tube; that is, the resonant frequency of a blown pipe or flute is not the same as its resonant frequency when excited by an outside source. However, there are several features about the actual initiation of the acoustic vibration that cannot be easily explained, and it is perhaps understandable that many modern textbooks describe the phenomenon in the same manner as did the earliest writers on the subject. Schlesinger (1939) discussed this in considerable detail. There is much evidence disclosing the incompleteness, at best, of this theory, but alternate theories, though better, are still somewhat unsatisfactory.

A demonstration can be made with an organ pipe, made of wood, 34 mm. square in cross-section, and 500 mm. long from the languid or block to the open end. Before correction, it is, therefore, one-half wave long for a 344 cps. tone; if an end-correction of 15 mm. is added, the pitch should be lowered. It actually does sound the F♯ below middle C, or 312 cps. If the mouth of the pipe is closed, and it is excited by an external source, it resonates at 339 or 340 cps.—not too far, perhaps, from the theoretical value.

The shape and approximate dimensions of a modern Boehm flute and of the "English flute" of a

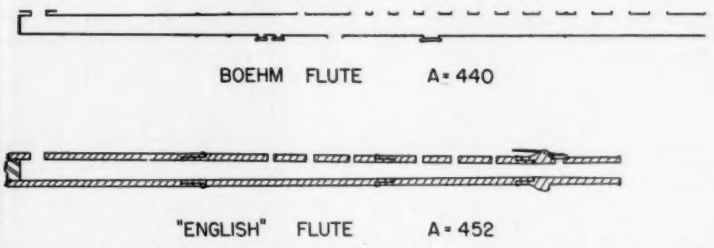

FIG. 1.—Cross-section of modern Boehm flute and of the "English flute." (One-fifth natural size; drawn to scale except for thickness of tube of Boehm metal flute, which is 0.020 inch.)

century ago are shown in Figure 1 which contains cross-sectional drawings, to scale, of these instruments. The inside diameter of the Boehm flute is 19 mm. at the open end, and it is cylindrical for approximately 450 mm. from the open end, tapering in a parabolic curve from this point to a diameter of 17 mm. at the stopper. The drawing shows all the holes, with the three normally-closed ones stopped off with pads. The two nearest the open end are open at all times except for playing the low C and C♯.

The lowest tone this flute sounds is "middle C," or C_4, at 261.6 cps., with all holes closed. Using the commonly-accepted end-correction factor of 0.6 R, the effective tube-length is increased to approximately 625 mm. One-half wave-length is 659 mm., and the standing-wave pattern may be drawn as at Figure 2 A. The tube appears to be "short at the embouchure end" by 34 mm.

The D_5, an octave higher, with a frequency of 587.3 cps. and a wave-length of 587 mm., is sounded with the first hole and the last two holes open, all others closed. Opening the first hole prohibits the formation of a node at that location along the tube (as shown in Fig. 2 A), and the wave-pattern might be drawn as in Figure 2 B, using the 34 mm. value just established as an "embouchure end allowance."

This is not quite as satisfying as the pattern in Figure 2 A, but it is acceptable. But the note D_6, another octave higher, which is fingered by closing the second, third, and fourth holes, must be represented as in Figure 2 C, and a satisfactory physical explanation of this pattern is not at all obvious.

The parabolic taper in the head-joint of the Boehm flute has long been a subject of discussion and dispute; its importance seems quite certain, but the reasons for that importance are obscure. The position of the stopper enters into the picture in a more easily rationalized manner. Normally the stopper is placed a distance from the embouchure hole equal to the diameter of the tube at that point, but its exact location is established by the intonation of the upper register of the instrument. Stopper position has little effect on the tuning of D_4, easily observable effect on D_5, and pronounced effect on D_6. From these and other data it is apparent that the tones in the

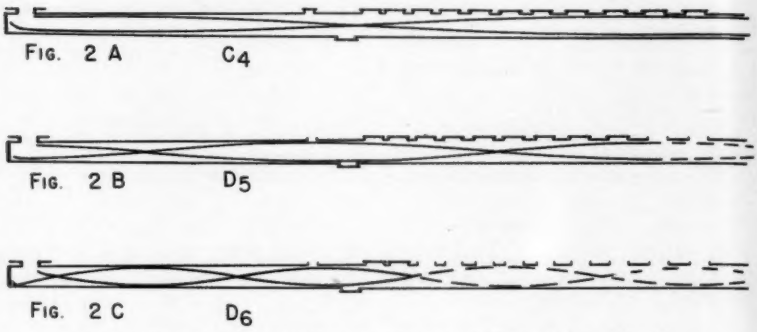

FIG. 2.—Standing-wave patterns within the Boehm flute for the tones C_4, D_5 and D_6.

lower register are governed principally by the lower part of the tube, and those in the upper register by the head-joint, the stopper position, and the embouchure.

There is no question that the player exercises very great influence over the formation of tones through embouchure adjustment or that, for the practised player, this adjustment is made without conscious effort. Accurate description of these adjustments is difficult, and the technique is correspondingly difficult for the student to learn. One of the reasons for beginning the present work was the hope of devising some useful techniques for teaching the flute.

Measurement within the Flute

In physical science, it is almost invariably the case that the act of making the measurement, or of applying the measuring instrument, will so disturb the conditions as to impair the investigation. This is especially true of the study of the flute; nearly any procedure that may be tried will change the operating conditions considerably.

To study the formation of the acoustic vibration, a simple flute was constructed of glass; it possessed only two holes, the embouchure hole and a single hole for fingering. The method of Kundt (1866) was first employed, using lycopodium powder, but even this light material seriously damped the vibration. Smoke and stroboscopic illumination were little more useful. The experimental difficulties in setting up a Schlieren system for this study are considerable, but some work has been successfully begun on this project, and it is to be continued.

Electric resistance strain gauges, mounted on the metal body of the flute, disturbed the mechanical vibrations appreciably, as indicated by perceptible changes of timbre of certain tones. The actual strains produced are small, although the internal pressures are high enough to be surprising to a person who has not played the flute and observed the often pronounced vibration of the flute tube and the closed keys.

Toepler and Boltzman (1870) measured pressure differences of the order of magnitude of three pounds per square inch in a sounding organ pipe, and it seems probable that corresponding pressures exist in the flute.

In a first attempt to survey the standing-wave pattern within the bore of the instrument, a probe less than one-tenth inch in diameter and carrying a pressure-sensitive pick-up (later, a velocity-sensitive element) was inserted from the open end. Excellent records were obtained, but the data were of negligible value, since the presence of the probe greatly affected both pitch and tone quality of the instrument. This was not unexpected, since this is an old method of changing the pitch of an instrument and is known to be unsatisfactory in many respects. The hot-wire anemometer element, responding to velocity alone and capable of extremely high sensitivity, can be so mounted as to cause little error from volume displacement; but, because it dissipates an appreciable quantity of heat while in operation, it introduces a new group of disturbing factors.

A desirable method would be to attach a large number of pressure pick-ups at intervals along the tube (attaching small-bore tubes through the side of the flute body for this purpose) so arranged that their presence would not appreciably disturb the characteristics of the instrument. The procedure seems quite feasible though expensive.

The quality and fit of pads is extremely important with regard to ease of playing, particularly in the lower register. Poorly fitting, leaky, porous or spongy pads all introduce difficulty. A demonstration of the effect of such leaks was arranged by carefully corking all the holes in an easy-playing flute, then opening a very small aperture in the first hole. It was shown that if this hole was covered with a 1/32-inch thick plastic cap, perforating this cap with a hole 0.020 inch in diameter completely destroyed the low D_4 of the instrument, sounding the octave, D_5, instead. Leaks in other locations produce corresponding adverse effects.

External Acoustics of the Flute

It is relatively easy to measure frequencies, amplitudes and phase differences in the area near but outside the instrument, although the presence of external reflecting objects, and the interference of the multiple sources of sound of the flute, are occasionally confusing. These are simple problems, however, compared to those connected with measurements within the instrument.

As a source of orchestral sound, the flute presents some practically unique characteristics. Brass instruments emit their sound almost entirely from the bell, the other woodwinds partially from the bell and partially from open holes near the bell. For most tones, the flute presents two separated sources—the embouchure, from which more than half the energy is radiated, and the open holes near the end of the flute, from which most of the remainder is radiated. Octave or speaker holes emit little sound compared to the others.

This fact makes possible an interference phenomenon which can seriously affect the tone of the flute, so

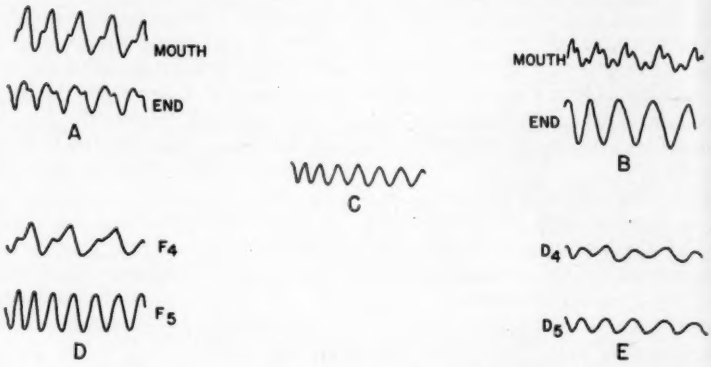

FIG. 3.—Oscillographic wave-forms: *A*, organ pipe, mouth and open end; *B*, recorder, mouth and open end; *C*, "English flute" of Figure 1, fundamental tone; *D*, Boehm flute, sounding F_4 and F_5; and *E*, Boehm flute, sounding D_4 and D_5.

far as the listener is concerned. The two sources of sound are separated from each other by a distance comparable to the half wave-length of many of the vibrational components present; thus, if the angle between flute and listener should be such as to make two of these components interfere destructively, a distorted tone would be heard. In fact this seldom happens, because the harmonic content of the upper register, where such interferences might most easily occur, is usually low. This behavior is illustrated by the case of the flue-type organ pipe, which emits quite different wave-forms at mouth and at open end (Fig. 3 A). When the pipe is set vertically, at a reasonable distance, these combine to produce a respectable sine-wave. In the recorder, the ancestor of the flute with a whistle mouthpiece, the composition of the two wave-forms is such that, even when combined, many harmonics are present. (Fig. 3 B).

No doubt since the first metal flute was made, there have been disputes as to which is better, metal or wood. It seems proper to say that they are different, but equally good; they will give equivalent performances in competent hands. As to tone, the Boehm flute excels, if its whole range is concerned; yet the older instruments, properly played, were often extremely good. In Figure 3 C is shown the wave-form of a note from the "English flute" of Figure 1, which may be compared to Figure 3 D, representing the F_4 and the F_5 of the Boehm flute of Figure 1. The lower note has a rather high harmonic content, predominantly first and second harmonics; the higher note has a much lower harmonic content. These wave-forms may be compared to the frequency spectra presented by Olson (1952) for the corresponding G.

Of the many other available illustrations of characteristic acoustic behavior of the flute, only one, of particular interest, will be given (Fig. 3 E). Two notes, the low D_4 and the D_5 an octave above it, were sounded; the difference in fingering is only

that the first hole is opened, prohibiting the existence of an antinode in the center of the tube. The two wave-forms look surprisingly alike, yet the tones sound entirely different. The explanation is that in the lower note there is a large component of second, third, and even fourth harmonics, producing difference frequencies between each other and between each component and the fundamental. Thus, a large part of the sound heard by the ear is actually beat tones having the same frequency as the fundamental. The magnitudes and phase relations for a satisfactory combination are somewhat critical, so that it is not surprising that good performance in the lower register of the flute demands both a good instrument and good playing.

As an illustration of what can happen when such a beat tone is produced, the organ pipe previously described can be made to sound its fundamental (with the end closed) and a note approximately an octave higher, but not harmonically related. Under the proper pressure, both notes are clearly heard simultaneously, and with them a strong beat at six or eight cycles per second. The condition is unstable, but definite. As with most beat-notes, the principal effect is subjective, but it can be shown on an oscillograph record.

Conditions for best performance of a flute are rather critical. Roughness in the bore or the holes, soft or leaky pads, or even a thick layer of dust, can produce an observable effect. The external acoustic pattern is readily distorted by surrounding objects, and internal disturbances are even more easily produced. Excepting for the lowest C♯ and C natural, for every note produced by the Boehm flute venting holes are open at all times, yet even minor obstructions in the open end impair the tone to some extent. The concept of acoustical impedance, widely used in the mathematical analysis of acoustic systems, often leads only to confusion when applied to certain instruments of the flute type.

Most of the design principles of flutes are empirical and, while they can usually be rationalized, they are not easily anticipated. Bulbous flutes, such as the aulos and the ocarina, tend to give purest tones, since they act like spherical volume resonators; flutes with a large length diameter ratio tend toward complex tones; flutes which depend entirely upon venting holes instead of an open lower end usually emphasize this tendency. Some flutes manage to break all the rules, as in the ancient Chinese and certain primitive flutes which employ a cylindrical bore and equally spaced holes of uniform size to produce accurate diatonic scales.

Summary

The paper has given a brief introduction to the historical background of the flute, described the generally accepted theory of vibrating air columns, and presented some data tending to correct some incomplete descriptive theory. Some acoustic data representative of modern instruments are presented. In addition to its general interest to the student of physics, the discussion may be of value to the student of music.

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SCIENCE EDUCATION, PSYCHOLOGY, AND SOCIAL SCIENCE

A PHILOSOPHY OF SCIENCE-ENGINEERING EDUCATION

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The knowledge of the physical sciences, inherited from the past and extended through research of the present, can have little impact on human living unless planned, systematic effort is made toward its utilization in practical applications. It is the function of engineering to create means by which physical science may be utilized for the benefit of society.

Civilization as a whole needs the knowledge, the inspiration, the material products of all lines of effort of all kinds of people. Physicist and poet, engineer and artist, astronomer and historian, biologist and economist—all men who seek knowledge, truth, beauty, and understanding—are adding in equal measure to the welfare of men.

The social scientist cannot hope to see his ideals of a more effective and peaceful social structure come to pass without the tools provided by medicine, public health, science, and industry. Nor is the engineer very effective or useful in a social organization which is unable to provide rudimentary civic orderliness and access to economic resources. Nor do men live happily, even with physical comforts and social and political stability, if they do not have access also to freedom, beauty, inspiration, and love.

It is occasionally claimed that art, music, and literature are beautiful, but that science and engineering are crass, materialistic, earthy, and practical. Who is to say that a symphony or the poems of Omar Khayyam are any "finer" than Newton's Laws of Motion or than the functional beauty of many modern engineering masterpieces such as the Golden Gate Bridge? A symphony may be played by 100 musicians under the baton of a master conductor, or by 50,000 scientists, engineers, and skilled mechanics playing a blueprint score to build a jet airliner. It should not offend those who receive inspiration from art and literature to suggest that others receive just as true and fine an inspirational experience from astronomy, physics, engineering, or social sciences. We should neither envy nor disdain those who have chosen other approaches to knowledge, truth, and beauty than the one we prefer.

Science and technology have become so important a part of the structure of modern American civilization that, like air and water, we have come to take them for granted

and even ignore their intrinsic value. The major objective of scientists and engineers is to make the world a better place in which to live. In an individual, a university, a company, a community, a nation, and in a world community we need knowledge and competence of many types; we need breadth of vision; we need not only intelligence but wisdom, and not only intellectual but also moral responsibility and leadership.

Like the profession of practicing medical doctors, the engineering profession is comprised of "practitioners," who utilize both the science and the art of their professions to obtain immediate answers to problems that face mankind.

Years ago, most engineers were self-taught, practical builders of machinery and instruments, surveyors, and constructors of bridges, roads, and canals. They became engineers after some informal education and on-the-job training and experience. Prospective engineers simply apprenticed themselves to an established engineer or got a mechanical job in a factory or shop, and developed by experience. The early medical doctors similarly were trained, primarily by experience as apprentices; and medical doctors are still required to serve several years as interns to assure adequate integration of medical science and art.

As science and practice in medicine and engineering moved ahead and became more complex, formal education in schools of higher learning became essential in both professions. The physical sciences of physics, chemistry, and mathematics provide the fundamental basis for the practice of engineering, as the biological sciences of biology, biochemistry, bacteriology, etc. provide the fundamental basis for the practice of medicine. In both professions emphasis is placed upon fundamental science, and applied science courses have been developed in universities to enable the future practitioner to integrate the science and the art and thus develop sound skill with the tools and techniques he will use in his profession.

An analogy may be drawn between the human body which is the field of practice of the medical doctor, and the integrated community or industrial plant which is the field of practice of the engineer. By training in surgery and internal medicine, the medical doctor learns to make a sound medical analysis and to prescribe proper treatment. Similarly, by training in engineering methods of analysis and synthesis, the engineer learns to make sound engineering analyses and recommendations on existing plants and to develop sound designs for future enterprises. In this respect the engineer might be considered to have attained a more creative level of accomplishment, since he can use his originality to create entirely new systems, processes, and products that did not exist before, whereas the medical doctor or medical scientist can assist Mother Nature in developing healthier people and can overcome most of their serious ailments, but he cannot create entirely new species. Of course, the human body is infinitely more complex than any engineering installation. Another facetious comparison is that the medical doctor can bury his mistakes, but the engineer has to live with his.

Scientific and engineering developments are worth bragging about

not because they are ingenious, or because they make the inventor a lot of money, but because they save human lives, reduce human suffering, and enable human beings to devote energy to things other than the grim struggle to satisfy the basic human needs for food, warmth, shelter, etc.

The philosophy of science-engineering education is similar to that in many other fields of university education. Stated in simplest form, the objectives are: 1) to learn to think clearly in terms of fundamental principles; 2) to learn to learn by oneself; and 3) to learn to assume responsibilities commensurate with freedoms desired.

Note that memorizing and reciting great masses of factual information are not included in the objectives. A large recognition vocabulary is necessary, but a well classified library makes readily available a storehouse of detailed information far beyond that of the most prodigious memory. The human mind appears to work more efficiently as an imaginative, logical, thinking device when it is not too heavily burdened with masses of details not essential to the problem at hand.

The present storehouse of knowledge is so vast, and it is expanding so rapidly, that there is a strong trend toward increased specialization in fields of study. A large university may list 3000 courses of study in its catalog. It would require 40 years to attend all of these courses. In the 40 years there would probably be added hundreds of more courses. Therefore, the tendency is to know more and more about less and less; the ultimate in this direction appears to be to know everything about an infinitesimal field of knowledge.

If we are to avoid a morass of confusion, duplication, and mediocrity, we must present knowledge in brief, understandable form in terms of fundamental principles. We must learn to think clearly and logically in terms of these fundamental principles. Mathematics is a very useful universal language in which most principles, of the physical sciences at least, may be expressed most concisely. An understanding of algebra and the simpler aspects of calculus and differential equations is adequate to permit progress to be made in mastering large fields of engineering knowledge. Simple scientific truths and principles stated in mathematical language are our best means of reducing our great storehouse of knowledge to a manageable size.

The science-engineering curriculum permits attaining a higher level of ability along this line, so the engineer can communicate with and work with the scientist at the endless frontiers of research and development. A common core of basic engineering subjects is retained, and some 20% of the time is devoted to social-humanistic courses. However, greater depth in the physical sciences and mathematics and greater flexibility are provided for by the elimination of the engineering major dealing with applications in a specified field such as electrical, chemical, civil, and mechanical engineering. The more flexible program permits selecting a sequence of courses oriented to the interests of the mature, imaginative student, and thus enables him to attain his goal more directly with the assurance that he

is well equipped to continue to "learn by himself" as he progresses toward full professional responsibility.

The use of symbols for the chemical elements and physical laws and equations is an analogous, simplified language. It might be noted that the improved thinking and communications permitted by the languages of physics, chemistry, and mathematics are available only to those who have learned these languages. All other people are mystified and a little afraid of these strange languages. In advancing civilization these scientific languages appear to have taken the place that was occupied by the classical languages in man's struggle for individual freedoms in the days of the Renaissance.

Philosophers, psychologists, businessmen, engineers, and military men have all made intensive studies of, and have arrived at similar procedures for, logical thinking. There is good agreement that the following are the most important steps involved in logical thinking in any field of knowledge: 1) visualize; 2) set objective; 3) make plans, assumptions; 4) work out plan; 5) complete; and 6) generalize.

1). The step *visualize* includes gathering together all pertinent information and sorting it out so it can be reviewed at will.

2). Setting the *objective* is essential to define the problem on which we wish to think logically and to solve. It selects from the large number of possible problems that might be selected from the mass of information we collected under item 1 and permits us to concentrate on a specific problem.

3.) All possible *plans* for attaining the objective should be stated and, if time is limited, the most promising plans selected for working up in detail. In developing a workable plan, it is usually necessary to make certain simplifying *assumptions*. Such assumptions must be carefully written down for clarity in thinking and for communication to others.

4). *Working* out the *plan* requires utilizing all the skills, knowledge, and resources available to attain the objective. This may be very time consuming.

5). *Complete* means to finish the job by making recommendations for action and following up to assure action has been taken. This usually involves communicating to others by means of written reports or by oral instructions.

6). *Generalize* includes the review of the actions taken under items 1 to 5 and drawing generalizations or fundamental principles from the results. This is most important in the learning process.

The engineering method of teaching by problem-solving attempts to instill in the student this habit of logical thinking, with the objective of developing the ability to make sound, intuitive judgments in complex problems without the detailed working out of plans listed as item 4. As a child learns to crawl, then walk, and then run, so the student gradually acquires skill and confidence in the use of the "steps in logical thinking" in more and more complex situations. As he "learns to learn by himself," he develops broad flexibility and a desire to attack new problems by logical thinking in terms of fundamentals. Developing intuitive judgment appears

to result from 90% perspiration and 10% inspiration, since most outstanding engineers, particularly those who have developed intuitive judgment to a high level and are successful in management of our large corporations in technological fields, have undergone intensive experiences, starting with emphasis upon items 3, 4, and 5 and gradually becoming skilled in items 1, 2, and 6. Their experiences appear comparable to those of the highly skilled medical surgeon who spends long hours on minor details of surgery until they are thoroughly mastered, and then apparently performs miracles in difficult and delicate operations with no apparent effort. This is also comparable to the experiences of the outstanding leaders in all of the arts and professions, such as artists, musicians, sculptors, writers, poets, etc. The internship, the apprenticeship, and the self-disciplinary training period are long and arduous, but they appear essential to attain outstanding results.

The essential, fundamental principles or tools that the science-engineer uses in carrying on his work are: 1) material balances; 2) energy balances; 3) equilibria; 4) rate processes, such as physical kinetics (mass, momentum, and energy transfer) and chemical kinetics; 5) economic balances; and 6) human values.

The utilization of all the above tools to give an integrated result is professional engineering when applied to problems falling within the broad province of engineering.

The above fundamental principles, or tools, are very simply stated. The *balances*, items 1, 2, and 5 merely state:

$$\text{Input} = \text{output} + \text{accumulation (inventory change)}$$

The usual concept of *equilibria* (item 3) is that of dynamic equilibria, *i.e.*, the steady state attained when opposing tendencies are just balanced. This applies to all forms of physical equilibria. Statics, thermodynamics, and statistical mechanics are very powerful tools in this field.

The rate processes (item 4) are based upon the simple concept:

$$\text{Rate} = \frac{1}{\text{resistance}} \times \text{driving force}$$

This rate concept applies to the flow of an electric current along a wire, to the flow of water through an irrigation system, to the flow of heat through a nuclear reactor, to the speed of a train or an airplane, to the rates of chemical reactions, etc.

Just as a skilled surgeon can perform miracles with a scalpel, which is not much different from the simple knife I carry in my pocket, so the engineer can perform miracles with the above simple engineering tools in the analysis and synthesis of problems involved in the utilization of science. In the past few centuries, by observation of almost countless experimental facts coupled with inductive thinking, man has established many laws, theories, and fundamental principles. The scientists have expressed many of these principles in differential equations, which then enable the scientists to use deductive thinking to plan further experiments and to advance knowledge. Similar quantitative deductive thinking by the science-engineer based on these fundamental principles permits him to solve problems involved in the applications of

science, but introduces the additional difficulty of applying boundary conditions to the equations which are dictated by the complex physical situations encountered in engineering applications. This involves a very high order of ability by individuals motivated by the utilization of science for the needs of man, as contrasted to the scientist who is more interested in the search for truth for its own sake. Practice without theory soon ends in sterility; while theory without practice is tempted to lose its way in metaphysical futility. It is the team of scientist and engineer that should be unbeatable.

Down through the ages, the job of the technologist, the engineer, and the applied scientist has been to develop methods of satisfying human needs. The people who have the need will work to acquire the device or service. They will pay for it. Hence, somebody makes some money. There is nothing wrong in making money, and it is vital to our way of life; but it is wrong to put the importance of the medium of exchange through which a need is met above the importance of the need itself. The engineer's contributions to society should be expressed in terms of human needs, and it should be clearly recognized that the engineer's emphasis on *economics* is merely as a convenient unit of measure of human needs. Although the engineer is not primarily interested in "*value judgments*" of "good" or "bad," he should be alert to such judgments as may affect matters in his field. It is the breadth of possible applications of fundamental concepts that assures versatility in the thinking of the science-engineer.

The objective of undergraduate engineering is not to give the student all the answers, but rather the methods of observation and thinking which will lead him to the answers. While our students gain facility in the application of scientific and engineering principles through intensive and extensive problem work, we recognize that these problems are packaged and delivered to the student with little effort on his part. Major emphasis in textbook problems is on items 3 and 4 of the steps in logical thinking, *i.e.*, on detailed planning and solving of well defined problems. Not infrequently this leads to the belief by the student that the engineering solution of a problem is more difficult than its recognition and definition. The converse is the fact. The problems encountered in industry are usually broad and unstated, and frequently indefinite and intermingled. The analysis of these more or less confused situations and their resolution into one or more discrete problems is almost invariably more demanding than the pertinent engineering solutions. The power to do this work rests on a mastery of principles rather than on a great proficiency in engineering calculations. While the latter is a necessary tool, it is only a tool. It is merely the servant of the ability to isolate and state the problem, *i.e.*, items 1 and 2 in the steps in logical thinking. It is the over-all ability not only to find the problems, but also to solve them, which is highly rewarded. This over-all ability is usually the result of a fruitful industrial experience built on a strong foundation of scientific knowledge. This strong foundation can be acquired best in

college. It is only engineering efficiency for the colleges to give the strongest possible background in the quantitative application of fundamental principles, since such quantitative thinking is very difficult to "learn by oneself." It requires long hours of arduous work, which is more effectively done in the friendly, competitive college atmosphere with the guidance and inspiration of an experienced faculty. The fruitful industrial experience can be acquired only in industry and must be learned by oneself. The ability to draw sound conclusions from insufficient data is a most important criterion of the successful engineer.

There is one thing the young engineer must understand. When he completes his academic training, he has not received his education, he has merely been equipped with a few tools with which to obtain it. He has reached the threshold of his professional education and is headed in the right direction. The remainder of his professional life will be spent in getting his education. From about 35 to 55 years of age is the period of greatest productivity. Certainly up to age 35 the young engineer should concentrate on gaining knowledge that broadens his capacities (learning by himself).

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WRITING THE SCIENTIFIC PAPER

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Reduced to simple definition, a good scientific paper is a clear, concise, and accurate record of work done, or things seen, and conclusions drawn.

Item follows item in orderly array. Items logically related are grouped. Ideally, each succeeding item is a natural, logical outgrowth of the one before. The ideal is seldom attained.

Each statement stands the test of truth and clarity. Not only is it so clear that it can be readily understood by scientists; it is so crystal clear that it cannot be misunderstood or misinterpreted—by even an editor.

The good scientific paper is written with unassuming simplicity and genuine humility. Its writer is plagued with no illusions that he alone can greatly change the course of world events. He knows that at work are many skilled scientists, of whom he is only one. He feels a rewarding glow if he senses that, in the eyes of fellow scientists, he has pushed back the curtains of darkness even a few inches.

The Approach

Scientists vary in their approach to the exertion involved in writing a paper. Some begin by making tortuous outlines that they discard after the first few hours of futile writing. Some begin by writing introductory or concluding sentences. Some begin by doodling. A few rare individuals think through the problem, make a well-organized outline of suitable simplicity, or complexity, and follow this outline to the bitter, exhausting end—or until the outline becomes the master, not the servant, of the writer.

Thoughtful planning should precede writing. Each writer-scientist should choose the approach that best fits his temperament, personality, and mood of the moment. Once he has made the momentous decision that the paper should be written, he should not wait long for the creative mood to descend upon him, or he may never begin. The creative mood can be created. Often it follows rather than precedes creation. The important thing in beginning a paper is to begin.

Form

The form of the scientific paper has a number of possibilities. It may contain one to several of the following sections:

Introduction.—In this section should be recited the reasons for writing the paper.

Acknowledgments. — Included should be names and identifications of only those persons who have given genuine help, not the names of those the author wishes merely to flatter. It may be made painlessly brief and included with the introduction.

Review of the Literature.—Here the scientist finds himself presented with an opportunity to reveal what kind of man he is. He can impress the neophytes in the field by putting in all references, whether or not he has consulted them, whose titles indicate that they are even remotely related to the subject of his paper. He can omit all references, implying thereby that he is pioneering in a totally virgin field. He can include references to papers written by his friends and omit mention of those written by scientists he regards as his enemies. He can follow a more ethical procedure and, after painstaking perusal of the literature in the field, include references to all those papers he has consulted that are truly pertinent to the subject.

Materials and Methods.—The explanation in this section should be detailed enough to allow other scientists to check on the authenticity of the work or to duplicate the procedures upon which the paper is based. As in other sections, good judgment is needed here to determine what material should be included and what omitted.

Main Body of the Paper.—Great latitude is possible in this section, which should include the results of the experiments to be reported upon and may include interpretations and conclusions. Negative results, sometimes more important than positive results, should not be omitted.

Discussion.—This section is a possibility but not a necessity. It is more easily justified for some papers than for others. It should be not merely a convenient depository for after-thoughts. If it is to justify the space it occupies, it should be considerably more than a rehash of results. It should clarify rather than confuse issues. It may be regarded as a convenient place for: 1) bringing together facts presented in various parts of the paper and pointing out any pertinent interrelationships that exist; 2) interpreting results broadly; 3) taking a refreshing, wide-eyed look at the width and depth of problems discussed in the paper; and 4) projecting whatever thinking may be induced by the paper at least a little way into the future.

Conclusions.—A separate section consisting of conclusions can be used advantageously in some papers to entice hasty fellow scientists to read something more than the summary. It should deliver faithfully what its name promises.

Summary.—The summary should be a chronological epitomization of the preceding parts of the paper. It should include all of the most important points of the paper and should introduce no new material. Even at the risk of repetition, the abstractions should be so worded that they are in unmistakable agreement with the originals.

Literature Cited.—Included in this section should be data on only those papers actually cited.

Appendix.—Use of this section should be avoided whenever possible. Most material important enough to be included with a paper is important enough to be included in the paper.

Blood and Sweat

The actual writing of the paper should be preceded by a complete emptying of the mind of the scien-

tist and the gradual sifting back into it of only those items pertinent to the subject. Rejected should be the pet hunches, blind spots, preconceptions, and prejudices that customarily serve as road blocks to right conclusions. Rejected at the writing of the first draft should be a too-conscious subservience to rhetorical trivia. Commas can be inserted in, or deleted from, the paper at a later date.

The thought process should precede the writing process, but, unfortunately, some writer-scientists reverse the procedure. Clear writing should, and usually does, result from clear thinking. Only by chance can clear writing derive from muddy thinking.

Common signs of muddy thinking are the following:

1.—Illogical or unrelated grouping of facts.

2.—Unjustified switch in point of view (sometimes indicated by change of subject, or of voice, as from active to passive).

3.—Use of obscure or doubtful antecedents for pronouns.

4.—Omission of vital facts or steps in procedure, interpretation, or conclusion.

5.—Needless repetition of facts.

6.—Inaccurate paraphrasing of references.

7.—Imprecise use of words, use of words in senses peculiar only to the author or a small group, or use of words for the sake of use of words.

8.—Drawing of conclusions not warranted by the facts presented —fallacious reasoning.

9.—Inclusion of only those data that are favorable to a desired conclusion, and exclusion of equally valuable data unfavorable to the conclusion.

Other common faults in scientific papers are represented by inaccuracy in making computations, in copying data, in copying quotations, and in copying items in the literature cited.

Many a writer-scientist assumes that the period at the end of the last sentence in the first draft marks completion of his paper. He is lamentably wrong. Unless he is an abnormal human being, he should at once reconcile himself to many additional hours of meticulous, arduous work. Probably he should not be satisfied with a second draft or even a third.

At this point, the writer-scientist should become the reader-scientist observing his paper critically from the lofty height of objectivity.

Many of the faults in scientific papers can be traced to reading failure—failure of the authors to read their manuscripts with thoughtfulness, thoroughness, objectivity, detachment, and patience. Patient, objective reading of early drafts will reveal fallacies and other faults that can be eliminated by the scientist of even average intelligence and ambition. Both patience and objectivity can be developed.

Some papers and some writer-scientists benefit from a resting period following one of the drafts. The resting period, which may be used for rethinking the problem and for reorienting and refreshing the writer, should not be allowed to become a rationalization for procrastination.

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ZOOLOGY

THE NUMBER OF SPECIES PER GENUS IN DIFFERENT ANIMAL CLASSES IN ILLINOIS

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The practice among descriptive zoologists of comparing concepts of taxa in their specific group with the concepts of their fellow taxonomists working on other groups is probably of some value. This practice encourages an interchange of ideas, increases the specialist's familiarity with animal groups outside his principal field of interest, and exerts a stabilizing influence on systematics as a whole. One of the more frequent comparisons made between groups is the relative size of genera (number of species included). Since the genus is a subjective category, the specialist who works with organisms having extremely large genera may be critical of the specialist in another animal group who assigns generic rank to smaller assemblages of species. Obviously, the criteria for erecting and recognizing genera vary in different kinds of organisms, and no absolute uniformity of generic concepts is possible. It is generally recognized, however, that the designation of too many small and monotypic genera indicates excessive generic splitting and thus tends to destroy the usefulness of the taxon.

To determine the degree of difference in relative size of the genus in different groups of animals, the number of species known to occur in Illinois has been divided by the number of genera represented:

$$\frac{\text{number of species in Illinois}}{\text{number of genera in Illinois}} = \text{mean number of species per genus}$$

The quotient is the average number of species per genus for each group. This formula has been applied to those animal groups of Illinois that have been recently surveyed.

For each of the vertebrate classes, the number of species occurring in Illinois is known within narrow limits of error, but the number of genera varies somewhat with the personal attitudes of different specialists. For each of the invertebrate classes, both the number of species and the number of genera are incomplete inasmuch as they are based on the few groups which have been well studied in Illinois. Moreover, although some of the studies are recent, others are old enough to contain genera that have since been subdivided. Thus, the averages obtained are not absolute, but they do provide a fairly reliable indication and an index for comparison of relative size of genera. For both vertebrate and invertebrate classes, it should be emphasized that the values obtained are comparable only to those computed for another geographic area of similar size and not to values derived for the fauna

TABLE 1.—Average Size of the Genus in Ten Animal Classes in Illinois.

Class	Species / Genera	Mean	Coverage
Mammalia	59 / 42	1.4	complete
Aves	262 / 166	1.5	Complete (Smith and Parmalee, 1955)
Reptilia	58 / 36	1.6	complete
Amphibia	35 / 16	2.2	complete
Osteichthyes	157 / 69	2.2	complete
Cyclostomata	5 / 3	1.6	complete
Insecta	2367 / 584	4.0	representative families among nine orders (Table 2)
Arachnida	372 / 174	3.0	spiders (Kaston, 1955) and pseudoscorpions (Hoff, 1949)
Crustacea	47 / 17	2.7	ostracods (Hoff, 1942) and decapods
Gastropoda	91 / 32	2.8	slugs and land snails (Baker, 1939)

of an entire country or continent.

For information on those groups with which I am least familiar (the plants, invertebrate classes, and the birds), I have relied on the publications cited and the unpublished estimates of the following specialists: L. K. Gloyd, T. E. Moore, H. H. Ross, M. W. Sanderson, R. B. Selander, and L. J. Stannard.

The general impression among taxonomists that vertebrate groups tend to have smaller genera than do groups of invertebrates and that insects outrank other kinds of animals in average number of species per genus is substantiated by the means shown in Table 1. There is not

however, the degree of difference suggested by a comparison of the total number of species in each of these groups or by a comparison of their maximum-sized genera. The ten indices fall within fairly narrow limits, and no one value is conspicuously out of alignment with the others. The general agreement of these averages indicates a remarkable uniformity of generic concepts among zoologists. It is equally noteworthy that the 2,200 species of ferns and flowering plants known in Illinois (Jones, 1950) average 3.0 species per genus, perhaps reflecting a uniformity among biologists in general.

Factors Regulating Average Size of Genus

The average size of the genus appears to be governed by a combination of factors. A conceivable correlation is that the number of species per genus is influenced by the general habits of the type of animal or its ability to utilize diverse habitats. If such a correlation exists, predominantly terrestrial organisms could be expected to have a greater variety of niches available for occupation than animals restricted to an aquatic environment, and the lampreys, which are mostly fish parasites with little host specificity, would have the least variety of available habitats. An examination of the mean values in Table 1 does not bear out this assumption. The higher vertebrates and terrestrial arthropods have a general ecological similarity, but they show little relationship to each other in average size of their genera.

The average number of species per genus would seem to be related to the degree of taxonomic refinement in the various groups, and the well-studied animals do appear to have smaller genera. Because of their size, the larger classes have not received the detailed attention and amount of time that have been devoted to the smaller classes, and it is reasonable to expect that poorly studied animals might have numerous, large "catch all" genera and some species which would ultimately be reduced to subspecific rank. In actual practice, however, the average number of species per genus, at least among the fishes, amphibians, and reptiles known in Illinois, has not decreased appreciably as their taxonomy became more refined.

The average size of the genus shows a general correlation with the total number of species within a prescribed geographic area. Thus, the two groups with the greatest and next greatest number of species (insects and arachnids) also exhibit first and second place rank in average number of species per genus. In the remaining eight classes, however, the total number of species in the class shows little relationship with average size of the genus, and number of species thus appears to be no more than a minor contributing factor to average genus-size.

An inverse correlation between average size of the genus and the size of the individual organism is indicated. The average size of the individuals in the invertebrate classes is appreciably smaller than that of the vertebrate animals. Conversely, average genus-size is greater among the invertebrates than among the vertebrates. The extremes in average body size among the ten

TABLE 2.—A Comparison of the Average Size of the Genus in the Amphibia and Reptilia.

	Amphibia		Reptilia	
	Species / Genera	Mean	Species / Genera	Mean
Canada	37 / 19	1.9	40 / 20	1.5
United States	142 / 38	3.7	236 / 88	2.6
Mexico	224 / 44	5.0	653 / 147	4.4

Data from the official check-lists of Logier and Toner, 1955; Schmidt, 1953; and Smith and Taylor, 1945, 1948, and 1950.

classes in Table 1 are represented by the mammals and, probably, the insects. These two classes also exhibit extremes in average number of species per genus. A given geographic area can support more small than large animals, inasmuch as the size of the individual shows at least a general relationship with the size of the niche, the home range, and the territory. It is probable that a given area contains a greater variety, as well as a greater number, of niches for organisms of small size than for large animals, and the area should support more and larger assemblages of related species as well as more individuals if organisms are small than if they are large.

The average size of the genus within a small geographic area seems to be primarily contingent upon the evolutionary and ecological success of the group of organisms in the region. Thus, in the so-called "headquarters" of an animal group not only are there more species and genera represented, but the average number of species per genus is also greater than in peripheral areas. This is illustrated in Table 2 by data for the classes Amphibia and Reptilia, both of which are, generally speaking, tropical groups.

In certain instances a class may not have one geographic area that can be recognized with certainty as the principal headquarters of the group, but within orders or families one or more such geographical centers may be discernible. If two centers are present a geographically intermediate locality is thus peripheral to both headquarters areas. Assuming that both headquarters have some genera in common, the group at the intermediate locality should have a higher species per genus aver-

TABLE 3.—A Comparison of Average Size of the Genus in Nine Orders of Insects in Illinois.

Order	Species / Genera	Mean	Coverage
Orthoptera.....	179 / 79	2.2	complete (Hebard, 1934)
Coleoptera.....	75 / 32	2.3	Meloidae and four subfamilies of Chrysomelidae
Plecoptera.....	49 / 19	2.4	complete (Frison, 1942)
Odonata.....	104 / 40	2.6	complete
Thysanoptera....	172 / 62	2.7	complete
Trichoptera.....	265 / 77	3.4	complete (Ross, 1944)
Ephemeroptera..	124 / 30	4.1	complete (Burks, 1953)
Heteroptera.....	325 / 72	4.5	Miridae (Knight, 1941)
Homoptera.....	1074 / 173	6.2	Aphidae (Hottes and Frison, 1931), Cercopidae, and Cicadellidae (DeLong, 1948, and Ross, pers. comm.)

age than a group at a locality marginal to only one center. Theoretically, an unusually high ratio then would indicate that the area in question is more or less centrally located in relation to the group headquarters; a slightly smaller value would suggest that the region studied is a slight distance from the center or that it is within the area of overlap of two separate centers; and a very small ratio would indicate that the area studied is on the periphery of a single headquarters region. The existence of two or more headquarters within some animal groups is virtually certain in nature as well as in theory.

THE CLASS INSECTA

Although the average number of species per genus of insects is based

on data from only a small fraction of the insect fauna of Illinois and is therefore subject to revision, it is of interest to tabulate the total genera, species, and means for each of the few orders represented. This information is summarized in Table 3.

The general relationships of these orders to one another, as indicated by the sequence in Table 3, are probably reliable, but data for two groups require qualification as they may not be representative of their respective orders in Illinois. The ratio for the Coleoptera, based on one predominantly western family and on only four subfamilies of a more typically Illinois family, may be too low. The ratio for the Homoptera, based on three families one of which (Cicadellidae) includes the exceptionally large genus *Erythroneura*, may be unduly high. With these possible sources of error in mind, the values for the various orders may be scrutinized in light of the factors discussed in the preceding pages.

The general habits of the groups and the degree of taxonomic refinement probably have negligible effects on the average size of the genus within the class Insecta. For example, it may be seen in Table 3 that the Orthoptera and Homoptera are distinctly unlike in average generic size, although both contain plant-eating insects with complete metamorphosis, terrestrial habits, and other ecological similarities. Similarly, it is apparent in Table 3 that the average size of the genus is not related to the degree of coverage or the publication date of the study cited. Average body size and total number of species in the different orders are probably related to average size of the genus, but neither is directly correlated with the various ratios. Disregarding the problematical data for the Coleoptera and examining the means in relation to the headquarters areas of the various groups, we can account for the relatively low values for the Orthoptera, Plecoptera, Odonata, and Thysanoptera by assuming that these groups flourish with greater success somewhere outside of Illinois. The Orthoptera could, in fact, be regarded as primarily a southern and western order, the Plecoptera as a boreal and eastern group, and the Odonata and Thysanoptera as predominantly tropical groups. At the other extreme, we would deduce that the Homoptera, Heteroptera, and Ephemeroptera are near their optimal environment in Illinois; although values for these orders in other regions are not available for comparison, their means in Illinois are above the mean for the class Insecta. The caddisflies have an intermediate ratio which would suggest either that Illinois is not on the extreme periphery of optimal environment for caddisflies or that Illinois is situated in a zone of overlap of two or more different caddisfly faunas.

Of the five factors which appear to influence the relative size of the genus, data provided by the insects suggest that for categories below the rank of class the order of importance is: 1) spatial relation of the area studied to the group headquarters; 2) average body size of individuals in the group; 3) total number of species in the area studied; 4) degree of taxonomic refinement in the group; and 5) habits of the

group or diversity of habitats available.

Summary

The genus is a subjective taxon but it is regulated by fairly uniform concepts among biologists. In 10 animal classes studied in Illinois, its average size varies from 1.4 species (mammals) to 4.0 (insects); the ferns and flowering plants in Illinois average 3.0. In general, vertebrate classes tend to have smaller genera than do invertebrate groups. The most probable factors affecting average size of the genus are: 1) spatial relation of the area studied to the geographic center of success for the group; 2) average body size of the organisms within the group; 3) total number of species represented in the area studied; 4) degree of taxonomic refinement in the group; and 5) habits of the group of animals or the diversity of habitats the component species may occupy. The relative importance of these factors may vary from group to group. An analysis of nine orders of the class Insecta indicates that for categories below the class, the factors rank in importance in the order given.

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Illinois Academy of Science Transactions, Vol. 49, 1956

THREE NEW SPECIES AND TWO NEW RECORDS OF THRIPS (THYSANOPTERA) IN ILLINOIS

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The subjects of this artiele are hard-to-find species. Although little is known about them, it seems worthwhile to report their presence and describe those that are new. For the past five years or more I have known that they inhabit Illinois; yet, despite repeated searches, not many individuals have been collected. Their niche in the general environment remains to be located. In the broad sense two are prairie species, two are woodland species that presumably occur on herbs, and one is a woodland species that occurs in the fallen leaf mold.

Types of the new species are deposited in the collections of the Illinois Natural History Survey.

Anaphothrips (Anaphothrips) sandersoni new species

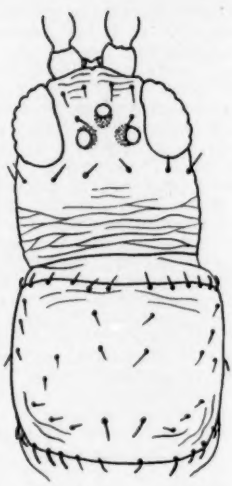
Female (macropterous).—Length distended, about 1.5 mm.; color yellow, except for apex of antennal segment V, all of antennal segments VI, VII, VIII, and IX, and tip of mouth cone which are brown; forewings, grayish yellow; ocellar crescents, red; head about as long as wide (Fig. 1); ocelli present; antennae nine-segmented; antennal segments III and IV each with a forked sense cone; mouth cone, long and pointed; posterior angles of pronotum without any long setae; abdominal tergite VIII with complete comb of setae (setae long and not fused with each other at base); abdominal tergite X completely split longitudinally.

Male (macropterous). — Length distended, over 1 mm.; color and general structure similar to female; abdominal sternites III to VII each with horseshoe-shaped glandular area; glandular area on segment VII often smaller and more crescent-shaped than horseshoe-shaped; no other glandular areas as turned in posteriorly as those in *A. catawba;* abdominal tergite VIII with complete posterior comb of setae; abdominal tergite IX with four stout spinelike setae.

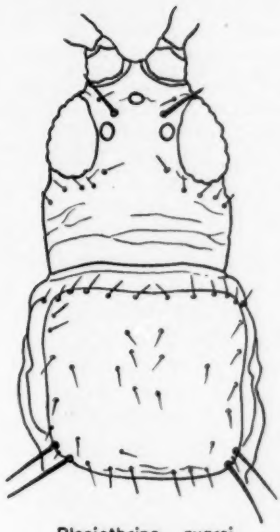
Holotype.—Female, Kinmundy, Marion County, Illinois, July 23, 1947. (Sanderson and Stannard) sweeping *Andropogon. Allotype.*—Male, Lawrence, Douglas County, Kansas, August 31, 1952 (S. C. and M. W. Sanderson) sweeping prairie plants. *Paratypes.*—24 ♀, same data as for holotype; 9 ♀, 3 ♂, same data as for allotype; 3 ♀, Elkhart, Logan County, Illinois, May 20, 1950 (Ross and Stannard) sweeping grasses and willows; 3 ♀, Farina, Fayette County, Illinois, July 23, 1947 (Sanderson and Stannard) on leaves of *Polygonum;* and 6 ♀, Farmer City, Dewitt County, Illinois, April 20, 1954 (L. J. Stannard) sweeping prairie plants.

This distinctive species is named for Dr. Milton W. Sanderson, one of our leading coleopterists, who took me to the prairie areas where these thrips were first found, who collected them later himself while on vacation in Kansas, and who has discovered many other new records of thrips in the states bordering the Mississippi River.

From the other yellow-colored species with complete posterior combs on abdominal tergite VIII that occur in the eastern states, *A. sandersoni* may be distinguished by the possession of fully developed wings, the nine-segmented condition of each antenna, the long mouth cone, and



Anaphothrips sandersoni
1



Plesiothrips ayarsi
2

FIG. 1.—*Anaphothrips* (*Anaphothrips*) *sandersoni* new species, dorsal aspect of head and prothorax.

FIG. 2.—*Plesiothrips ayarsi* new species, dorsal aspect of head and prothorax.

by the coarser type of head and pronotal striations.

This species is apparently limited to the midwestern prairie region.

Plesiothrips ayarsi new species

Female (macropterous).—Length distended, about 1.3 mm.; bicolored, brown and yellow; head, antennal segment I, most of segment II except apex, segment IV in apical half, segment V except pedicel, all of segments VI and VII, posterior half of abdominal segment IX, and all of abdominal segment X, brown; rest of body yellow, except prothorax which is faintly clouded with brown; forewings light but with some light gray tints; ocellar pigments red; body with red subintegumental pigment, especially extensive in thorax; head longer than wide; inner postocular setae near eyes, arising anterior to other postocular setae (Fig. 2); prothorax with three pairs of posterior minor setae between epimeral pairs; abdominal sternite III without glandular areas; abdominal sterna without accessory setae.

Male (macropterous).—Length distended, slightly over 1 mm.; color darker than female; almost entirely light brown; head, antennae, and terminal abdominal segments darkest, and apical portions of leg segments and anterior abdominal segments lightest.

In structure the male is like the female with the following exceptions: antennal segments IV, V, and VI enlarged as usual for males in this genus and segments IV and V each with ring joint; abdominal sternites III and IV each with pair of small circular glandular areas; and abdominal tergite IX with usual two thornlike, posterior, marginal projections.

Holotype.—Female, Fountain Bluff, Gorham, Jackson County, Illinois, August 16, 1950 (Evers and Stannard) hill prairie. *Allotype.*—Male, same data as for holotype. *Paratypes.*—1 ♂, 5 ♀, same data as for holotype; 1 ♀, Karbers Ridge, Hardin County, Illinois, August 18, 1950 (Evers and Stannard) hill

prairie; 1 ♀, Vienna, Johnson County, Illinois, August 17, 1950 (Evers and Stannard) hill prairie; 3 ♀, Forest City, Mason County, Illinois, September 11, 1953 (Ross and Stannard) sand prairie; 1 ♀, Monticello, Piatt County, Illinois, October 3, 1939 (M. D. Farrar); 1 ♀, Elgin, Kane County, Illinois, October 10, 1952 (Ross and Stannard) prairie on gravelly moraine; 1 ♀, Mt. Magazine, Logan County, Arkansas, July 16, 1949 (Sanderson and Stannard) hill prairie; 1 ♀, Von Ormy, Bexar County, Texas, July 27, 1953 (J. S. Ayars) grasses.

This species is a southwestern derivative; at least its range outside of Illinois is located entirely to the southwest. It is named for Mr. James S. Ayars, Technical Editor for the Illinois Natural History Survey, who collected the only Texas specimen of this species and who for many years has collected large numbers of other species to augment our knowledge of the thrips of this country.

From the closely related *P. perplexus*, *P. ayarsi* may be distinguished by the lighter color of the abdomen and thorax and by the placement of the inner postocular setae. In *P. ayarsi* these setae are placed more forward on the head and nearer the eyes, whereas in *P. perplexus* they are placed farther back and more medially on the head.

In Illinois this thrips is mostly confined to sand or hill prairies. Its distribution is disjunct and suggestive of the distribution of a relict species.

Thrips sylvanus new species

Female (macropterous).—Length distended, about 1.4 mm.; general color dark brown; antennal segments I and II dark brown; remainder of antennae bright yellow except often fading into brown in segments VI and VII, and sometimes fading into brown in segment V; apexes of tibiae and all of each tarsus yellow, fore tibiae being lightest; ocellar pigment red; forewings abruptly pale at base, uniformly brown in remainder of wing; prothorax with few (at most 3 or 4) pairs of setae on median part of notum; major posterior lateral setae fairly short; most of metanotal shield with hexagonal reticulations; forewings usually slightly upturned at tip; forevein with only two apical setae; posterior setae of intermediate abdominal sterna disposed along edge, median pair of these setae not moved anteriorly on sternum except on abdominal segment VII; no accessory setae present on abdominal sterna; posterior margin of abdominal segment VIII fringed with scalelike projections; most other abdominal segments similarly fringed but with scalelike projections weaker.

Male (macropterous). — Length distended, about 1 mm.; general color and structure similar to female; small sternal abdominal glands present on segments III to VII, gradually changing from eliptical on segment III to nearly circular on segment VII; Illinoian specimens tend to have antennae lighter in color—in one Illinoian paratype from Valmeyer, antennae entirely bright yellow from segment III to VII.

Holotype. — Female, Chimneys Camp Ground, Great Smoky Mountains National Park, Tennessee, August 31-September 1, 1948 (Ross and Stannard) sweeping woods. *Allotype.*—Male, same data as for holotype. *Paratypes.*—4 ♀, 1 ♂, same data as for holotype; 1 ♀, Valmeyer, Monroe County, Illinois, July 19, 1948 (Smith and Stannard) sweeping in woods; 1 ♀, Marshall, Clark County, Illinois, May 13, 1949 (Ross, Gloyd, Stannard) sweeping woods.

This thrips has been collected in Illinois and Tennessee several times over the past few years. Always it has been taken from woodlands in miscellaneous net sweepings without knowledge of its specific host plant or plants.

From previously described eastern species of *Thrips*, *T. sylvanus* may be distinguished at once by the presence of a series of scalelike projections along the posterior margin of the tergum of abdominal segment VIII. All other species of *Thrips* found within the range of *T. syl-*

vanus possess, on the posterior margin of abdominal segment VIII, either a series of setae that form a comb, or a series of scalelike projections which are tipped by fine filaments resembling setae, or setae only at the sides, or the margin is entirely bare.

New Records for the State of Illinois

Chaetanaphothrips orchidii (Moulton).—This species has been taken in woodlands in four localities as enumerated later. Neither the food plant nor the exact habitat preferred was observed because in every instance they were taken unknowingly while sweeping all sorts of vegetation in the forest undergrowth.

I restrict *C. orchidii* to those individuals which have no setae immediately next to the fore ocellus, which lack sternal abdominal glandular areas in the female, and which have the outer epimeral pair of setae proportionately longer than the same setae in *C. signipennis*. In my opinion, these characteristics are of specific significance and not merely "form" differences as Hood claimed in 1954.

That *C. orchidii* and *C. signipennis* are most likely different species, and not diploid and haploid forms of a single species (Hood, 1954), is based on the following: 1) Hood offered no evidence (cytological or otherwise) for his statement that one was haploid and the other diploid. Rather, Hood's contention, as presented in its entirety, was a baseless guess. Furthermore, to my knowledge, female insects are not haploid; 2) *C. orchidii* (as defined here) apparently occurs wild in many places in North America and possibly in South America but not wild in other areas of the world; and 3) *C. signipennis* apparently is host specific to (or prefers) bananas. Since bananas are "native to tropical Asia, Africa, Australia and adjacent islands" (Bailey, 1943), it could be presumed logically that the banana's thrips, *C. signipennis*, also is native to the Old World.

Seemingly, *C. orchidii* and *C. signipennis* were allopatric entities at some time before widespread human commerce. Because in many regions the two species now occur side by side is no reason to assume that they interbreed. Even if they do interbreed, there is no reason to suspect that one is haploid and the other diploid.

The discovery of *C. orchidii* in the wild in Illinois indicates that this species has a wider temperature tolerance than previously thought. Watson (1927) considered this thrips to be native to the warm regions of America, being distributed as far north as Florida. On the other hand, Pelikan (1954) surmised that it was native solely to the tropical northern coast of South America. The discovery that a supposed tropical species does extend into the midwest is not unusual. Many thrips have been found to have extensive ranges stretching from deep in the tropics north to Illinois and even Michigan.

Illinois specimens.—3 ♀, Oquawka, Henderson County, September 8, 1947 (Ross and Stannard) sweeping herbs in woodland; 1 ♀, Valmeyer, Monroe County, July 19, 1948 (Smith and Stannard) sweeping herbs in woodland; 1 ♀, Eldred, Greene County, June 7, 1949 (Sanderson and Stannard) sweeping

herbs in woodland; and 1 ♀, Carlyle, Clinton County, August 15, 1951 (Ross and Stannard) on dead branch.

Preeriella minuta Hood. — This species, as its name suggests, is one of the smallest thrips of our fauna. To date it has been found at seven widely-scattered localities within the state. All of these areas are outside the region of Wisconsin glaciation. It would seem, therefore, that the flat, poorly drained country that once was covered by the Wisconsin ice lobe acts as a barrier to the northward or eastward extension of the range of this thrips.

Originally *P. minuta* was described from Florida. It was considered to be a rare thrips, hardly known to most thysanopterists except by its description. Until recently its presence in Illinois was not suspected; in fact, several years ago, it would not have been listed as a possible inhabitant of states even farther south.

On July 18, 1949, Dr. M. W. Sanderson and I visited Eureka Springs in the Ozarks of Arkansas and collected a sample of leaves from the forest floor. In those leaves one specimen of *Preeriella minuta* was discovered, much to our surprise and delight. Thereafter in Illinois, we began an intensive search for this thrips, especially in the hills near or in the Ozarks. A year later a specimen was turned up at Herod, an area in the Shawnee Hill region of Illinois, and again this thrips was found in leaf mold. Since then we have collected more than a dozen individuals, always in leaf mold and always by seep areas or in very damp, decaying leaves. Besides the Illinois and Arkansas material, we have taken specimens in Mexico and in Texas.

Illinois specimens.—1 ♀, Herod, Pope County, May 5, 1950 (Sanderson and Stannard) forest debris; 1 ♀, 1 ♂, Florence, Pike County, October 1, 1953 (Smith and Stannard) leaf mold by spring; 2 ♀, Olive Branch, Alexander County, February 3, 1954 (Smith and Moore) forest debris; 6 ♀, 3 ♂, Pana, Christian County, April 7, 1954 (Smith and Stannard) forest debris; 2 ♀, Carthage, Hancock County, April 18, 1954 (T. E. Moore) forest debris; and 2 ♀, Pyatts, Perry County, April 11, 1956 (L. J. Stannard) fallen leaves in bottomland forest.

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CYSTICERCUS FASCIOLARIS AND CAPILLARIA HEPATICA IN RATTUS NORVEGICUS

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Borrel (1907, 1909; see also Roux, 1906), one of the first investigators to test the parasitic hypothesis of the etiology of cancer, examined the livers of wild rats, *Rattus norvegicus* and *Rattus rattus*, for the presence of *Cysticercus fasciolaris*, the larval stage of the cat tapeworm, *Taenia taeniaformis*, and found a wide variation in the incidence of this parasite in different localities. The frequency of occurrence of liver sarcoma in infected wild rats was consistently low. Since all wild rats as well as experimental rats thus infected did not develop cancer of the liver, Borrel proposed the idea that a virus carried by some cysticerci but not others was responsible for the initiation of the sarcomatous condition. Further evidence indicating that *C. fasciolaris* may act as a sarcoma-virus-carrying parasite was obtained by Borrel and Larrouse (1931) and these workers (1932) demonstrated the development of both dendritic and diffuse adenoma in rats infected with *C. fasciolaris*. Bridre and Conseil (1909) examined 2000 wild rats, *R. norvegicus* and *R. rattus*, in Tunis and found 800 (40%) infected with *C. fasciolaris* but only 5 liver tumors were found, 4 of which contained strobilocerci. Further studies by Bridre and Conseil (1910) of 3800 wild rats from Tunis and 1970 wild rats from Algiers revealed, respectively: 760 (20%) infected with *C. fasciolaris* but only 2 showing liver sarcomas and 614 (31%) infected with *C. fasciolaris* but only 4 showing liver sarcomas. McCoy (1909) reported on autopsies of 100,000 American wild rats, *R. norvegicus*, at the Federal Plague Laboratory in San Francisco and stated that 22 primary tumors of the liver were seen, in 12 of which he found *C. fasciolaris*. The number of rats parasitized by this form in McCoy's study unfortunately is not mentioned. Due to the large numbers of animals examined and the speed deemed necessary the search was at best a cursory one. This worker claimed that where there was distinct tumor formation the parasite was almost invariably dead and partly disintegrated. In this connection, Hiyeda and Oiso (1929) in a study of wild rats, *R. norvegicus* and *R. rattus*, infected with *C. fasciolaris* claimed that polymorphous sarcoma of the liver resulted from dead or inactive worms while spindle cell sarcomas were developed around cysts containing live, active larvae. In another study during the attempt to eradicate the plague in San Francisco, Woolley and Wherry (1911-1912) reported 22 spontaneous tumors of the liver in *R. norvegicus* observed in routine autopsy of 23,000 animals. Again, a count was not made of rats parasitized with

C. fasciolaris and only 3 of the 22 tumors noted were sarcomas containing *C. fasciolaris* strobilocerci. More recently Tsuchiya and Rector (1936) found 72 out of 100 *R. norvegicus* from the St. Louis area infected with this liver parasite, but no sarcomas were noted. Brumpt (1934) encountered *C. fasciolaris* in 288 of the 750 *R. norvegicus* examined in Caracas. From 1 to 5 cysts were observed in individual rats but in none was there evidence of liver sarcoma. More recently Calera *et al.* (1950) found 40 of 400 *R. norvegicus* in Panama City and suburbs infected with *C. fasciolaris* and Li and Hsu (1951) recorded 165 cases of *C. fasciolaris* infection in 358 rats, *R. norvegicus* and *R. rattus*, from the Taiwan area in Formosa. No reference was made to liver sarcomas in either of these latter two studies.

Examination of 532 *R. norvegicus* obtained from the city dump area of Bloomington, Illinois, revealed the livers of 428 animals (80.5%) infected with *Cysticercus fasciolaris* strobilocerci and the livers of 127 animals (23.9%) infected with the nematode, *Capillaria hepatica*. It was not the original intention of the authors to examine rats for this roundworm. However, since nests of eggs (Fig. 1) of this parasite were observed along with cysticerci in the livers of some of the first animals examined, the decision was made to record its incidence. It is interesting to note that only 10 of the 127 animals harboring this liver nematode were found infected with it alone; the rest (117) showed livers infected with both *C. fasciolaris* and *C. hepatica*. While no particular significance relating to this association of a cestode and a nematode parasite in the liver of the wild rat has been definitely established, it is entirely possible that trauma of the liver caused by invasion by *Taenia* oncospheres could facilitate a portal of entry for the larvae of *C. hepatica*. According to Luttermoser (1936) the incidence of this nematode in wild rats varied considerably in different areas and has been found to be as high as 77% in the District of Columbia and 85.6% in Baltimore, Maryland. Fulleborn (1924) and Luttermoser (1938a, 1938b) have shown that the life cycle of *C. hepatica* is direct from rat to rat without an intermediate host. However, according to these workers, the eggs to be infective must first be exposed to air until embryonated. Upon ingestion of embryonated ova, larvae are hatched in the intestine, pass through the wall of the caecum into the blood stream, and are carried to the liver. There is no evidence that the parasite is capable of inciting sarcoma of the liver.

The livers of all wild rats obtained for the study reported here were examined within two to four hours after the animals were killed. Gross inspection of each liver for cysts was followed by careful slicing of the liver with a sharp scalpel to locate cysticerci and egg nests of *C. hepatica*. Infected tissue was preserved in Bouin's, sectioned, and stained with Delafield's hematoxylin and eosin.

Cysts containing *C. fasciolaris* found in individual rats varied from 1 to 13 in number and ranged from 2 to 9 mm. in diameter (Fig. 2). Mode and mean of numbers of cysts in infected rats were, respec-

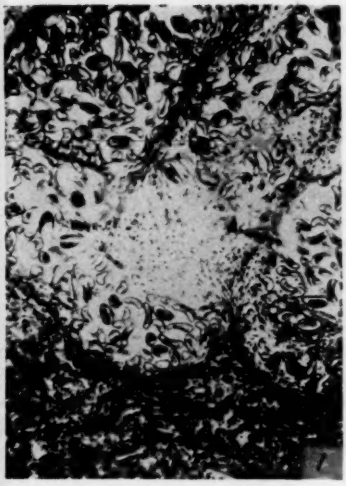

FIG. 1.—Photomicrograph of nests of *Capillaria hepatica* ova in liver of wild rat. 85x.

tively, 5.0 and 5.03. Strobilocerci when expelled from cysts measured from 2 to 8 cm. in length (Fig. 3). Specimens exhibited the characteristic scolex with 4 suckers and a rostellum bearing a double row of 32 to 44 hooks. *Taenia taeniaformis* developed in 6 experimental cats in 70 to 90 days following the feeding of cysticerci from captured wild rats. With reference to the life cycle of this organism it is interesting to note that the number of adult worms found in 50 cats in this area varied from 1 to 7 per cat with an incidence of 80% infection. Mode and mean of number of worms in infected cats were, respectively, 3.0 and 3.2. In this connection, Cross and Allen (1948) found 19 of 51 cats in Chicago infected with this tapeworm. Mann and Fratta (1952) found 8 of 100 cats in northern New Jersey harboring *T. taeniaformis*, and Miller (1932) found the rather astounding number of 22 mature and 2 immature *T. taeniaformis* in one cat.

None of the 428 wild rats found infected with *C. fasciolaris* in this study had developed liver tumors, such as were found in any of the studies referred to above, or polymorphous and spindle cell sarcomas as described by Bullock and Curtis (1920, 1925, 1928) and Curtis, Dunning and Bullock (1934) in experimental rats. Histological evidence of cellular and tissue changes which apparently do lead in some cases to liver sarcoma in regions adjacent to encysted larvae (Curtis and Bullock, 1924) were observed in 5 of the 428 infected rats. Areas of fibrosis in and near the cyst wall with abnormal cells proliferating from, and in both close and remote association with, the capsules surrounding strobilocerci together with

FIG. 2.—Photograph of *Cysticercus fasciolaris* cysts in liver of wild rat. 0.5x.

FIG. 3.—Photomicrograph of *Cysticercus fasciolaris* strobilocercus. 8x.

pronounced eosinophilic necrosis were observed in these few animals but no definite sarcomas had developed. It may be that because of the close cat and rat association in this area, rats do not live long enough after acquiring the infection to develop liver sarcoma. The results of this study are in agreement with the early work of Borrel (1907, 1909) and with other studies in that, while *C. fasciolaris* may occur in a fairly high percentage of wild rats, the incidence of cysticercus sarcoma is very low.

Bullock, Curtis and Dunning (1920, 1925, 1928, 1934) over a period of about 14 years infected thousands of laboratory rats with *C. fasciolaris* and observed the progression of liver tumors in many of these animals. Various types of malignant tumors were studied and in most instances were found during the 6-month period between the 11th and 17th months following infection. These investigators mentioned the strong probability of a sarcoma-inciting agent associated only with certain individual larvae, which is in agreement with the earlier contention of Borrel (1909). However, no virus or other cancer-inciting agent has ever been demonstrated to be in association with cysticerci. The problem of why liver sarcomas develop in some rats infected with *C. fasciolaris* but not in others harboring the same parasite has not been solved.

Studies on the details of progressive tissue changes in the livers of white rats experimentally infected with *C. fasciolaris* and attempts to infect golden hamsters in this laboratory are nearly completed. Findings thus far in white rats have revealed: 1) a remarkably high tolerance of extremely heavy infections; 2) further evidence of early pre-sarcomatous tissue changes; 3) additional data on early developmental states of the parasite; and 4) several liver sarcomas associated with *C. fasciolaris*. One accidental infection has been reported in the golden hamster, *Mesocricetus auratus*, by Wantland (1953). These rodents are refractory to this parasite.

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SUMMARY

Examination of 532 wild rats, *Rattus norvegicus*, showed the livers of 428 animals (80.5%) infected with *Cysticercus fasciolaris* strobilocerci and the livers of 127 animals (23.9%) infected with *Capillaria hepatica*. Cysticerci found in individual rats varied from 1 to 13 in number (mean 5.03) and ranged from 2 to 9 mm. in diameter. The livers of five of the animals infected with *C. fasciolaris* showed cellular and tissue changes which may lead in some cases to liver sarcoma, but no definite liver tumors were observed. *Taenia taeniaformis* devel-

oped in experimental cats after feeding cysticerci from captured rats. White rats fed large numbers of *T. taeniaformis* ova developed extremely heavy infections which were tolerated very well.

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EFFECT OF CARDIAC GLYCOSIDES ON POTASSIUM CONTENT OF SKELETAL MUSCLE OF RANA PIPIENS

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Introduction

To the surprise of many clinicians, cardiac glycosides affect tissues other than cardiac muscle. This paper is intended to be a preliminary report concerning the effect of certain cardiac glycosides on the potassium content of amphibian skeletal muscle.

Methods

In the experiments where whole-leaf digitalis was used, the material was prepared as follows: a quantity of dried powdered whole leaf digitalis (S. B. Penick and Co., Chicago) was placed in a beaker with a quantity of modified Ringer's solution (Aronson, 1954). The mixture was slowly brought to a boil; it was allowed to stand, covered, at room temperature for 72 hours, and the solution was filtered and stored under refrigeration until needed.

Where percentages are indicated they refer to the amount of the prepared digitalis solution in Ringer's solution. In those experiments where the frogs are said to be digitalized, the frogs had been injected intraperitoneally with 1.25 cc. of the undiluted digitalis solution per 20 gms. of body weight. It had previously been determined that 2.5 cc. of the digitalis solution per 20 gms. of frog weight represented the L.D. 60 of this preparation.

Where digitoxin was the agent to be tested, the solution was made up in Ringer's solution in proportion to the human digitalizing dose of 1.25 mgm/70 kgm. body weight. The muscle was then equilibrated in this solution. Where a fraction of the digitalizing dose was indicated, the aforementioned solution was diluted with an appropriate amount of Ringer's solution.

The gastrocnemius muscle of the frog was excised and then equilibrated in Ringer's solution for one hour. After equilibration, the muscle was placed either in the Ringer's solution containing the material tested or in fresh Ringer's solution for two hours in the case of the controls.

Muscles from digitalized frogs were treated as though they were weighed. Muscles were then placed in a 50% solution of trichloroacetic acid for at least 24 hours. The denatured tissue and the solution, in which it had been bathed, were blended in a Waring blender. The volume of the blend was measured. An aliquot of the homogenate was diluted to determine the potassium content with a Coleman flamespectrophotometer model No. 21. The potassium content was calculated in terms of mEq.K/kgm. wet weight of muscle.

Results

The data are summarized in Table 1.

TABLE 1.—Effect of Cardiac Glycosides on Skeletal Muscle.

	No. muscles	mEqK/kgm.	S.D.	P
		whole leaf digitalis		
Control	22	62.2	13.8	.....
10% digitalis	12	44.9	10.9	>5%
5% digitalis	12	48.6	13.3	>5%
1% digitalis	14	76.6	9.9	>1%
		digitalized frogs		
Control	11	58.6	7.6	>0.1%
Digitalized frogs	11	78.0	5.9	.....
		digitoxin		
Control	13	70.9	14.8	.....
Digitalizing dose/4	13	70.0	21.3	.....
Digitalizing dose/2	13	90.4	20.0	>5%
Digitalizing dose/1	13	74.7	16.9	.....

DISCUSSION AND SUMMARY

One may conclude from the data in the table that there is an optimum concentration of cardiac glycosides which, when applied to skeletal muscle of frogs, will enhance the potassium content of this muscle. It is also apparent that when this level is exceeded, there is a loss of potassium from skeletal muscle. In Goodman and Gilman's text of pharmacology (1955), as well as in other pharmacology texts, there are statements indicating a rise in serum potassium following digitalization. These observations correlate quite well with the data presented and indicate a possible source of the excess potassium. No attempt is made at this time to set up any hypothesis concerning either the mechanism of action of digitalis or that through which potassium binding may be altered.

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A COMPARISON OF PAST AND PRESENT POPULATIONS OF FRESH-WATER MUSSELS IN SOUTHERN ILLINOIS

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Naiads or fresh-water mussels apparently constituted an important source of food for much of the Indian population occupying Illinois in prehistoric and early historic times. The shells were used as tools (hoes, cups, dippers, etc.) and for various body ornaments, beads and pendants, as well as temper material for pottery. The hard shells of these mollusks are extremely resistant to weathering and general deterioration; they are usually well preserved in nearly all soil types. Because of this resistant quality, shells removed from Indian camp sites, kitchen middens, and refuse pits serve as an index to the relative abundance and species composition of past populations of mollusks, as well as providing an insight to the general climatic and habitat conditions prevailing at that time.

Introduction

Table 1 is a composite list of the species of river mussels and their numbers which were encountered in eight Indian sites in southern Illinois. More emphasis will be placed on the Modoc Rock Shelter, Peter's Cave, Nigger Springs and the Rosiclare sites because of the larger numbers of shells examined from each and because of the more extensive collecting in the rivers at or near these sites. Naiads found in the remaining four sites, as well as others of particular interest, will be discussed only briefly.

In the summer of 1952, the Modoc Rock Shelter Site, located approximately two miles southeast of Prairie DuRocher, Randolph County, Illinois, was excavated by the Illinois State Museum. The following summer further excavation of this Archaic Site was undertaken jointly by the Illinois State Museum and the Department of Anthropology of the University of Chicago. A preliminary report of this site was prepared (Fowler, Winters and Parmalee, 1955). A large number of bone and shell remains was removed from this site, the majority of which were identified by the author. The Modoc Rock Shelter is of particular interest since radiocarbon tests (Libby, 1954) date the lower occupation levels (approximately 24-26 feet below the original surface) at about 9,000 years B.C. Mussel shells were not encountered below the 20-foot level (with the exception of four valves), and the greatest concentrations occurred throughout the levels that were 9 to 17 feet in depth, dating 3,000 to 3,600 years B.C.

The second major site considered is one that was probably occupied by a Middle Mississippian Culture between 1,200 and 1,500 A.D. It is the Nigger Springs Site, located approximately three miles southeast of Equality, Gallatin County, Illinois, and judged to have been about 30

acres in size. Peithman (1953) has described this site in some detail. It is of special interest since there is, located near the center of the site, a flowing saline spring. Formerly there were two such springs, but the second has since been filled in and the exact location is unknown. Peithman (1953:67) stated that "The Indians made use of the site in two ways: (1) procuring salt by evaporating the brine from the springs; and (2) manufacturing salt-pan pottery vessels used in the evaporating process".

In his examination of the Nigger Springs Site in November, 1952, Peithman (1953:67) excavated three test pits (each a five-foot square) "to determine the depth of the midden deposits and to check the potsherd stratigraphy of the site". The shell remains removed from these pits, plus those obtained from two additional surface collections made by the author in July and August, 1954, are combined and listed in Table 1.

The Orr or Rosiclare Site was occupied by a Middle Mississippi Culture during the period of approximately 1,400 to 1,600 A.D. It is one mile east of Rosiclare, Hardin County, Illinois, and constitutes roughly 25 acres of a north bluff overlooking the Ohio River. A total of 238 mussel valves were removed from a single test pit that measured approximately 5 by 5 by 3 feet. The large number of shells obtained from this kitchen midden indicates that river mussels provided an important source of food to these people.

The rock shelter referred to as the Peter's Cave Site is located approximately 11 miles northwest of Murphysboro, Jackson County, Illinois, now within one-half mile of Big Kinkaid Creek. Although material from the lower levels is apparently Archaic (a period ending about 2,000 B.C.?), the majority of remains are from a Late Woodland Culture, a time period range of about 800 to 1,200 A.D. The relatively large quantity of shell found at this site again points to the significance of river mussels in the diet of the aborigines of Illinois.

During the latter part of 1953 and in the summer and early fall of 1954, the author collected approximately 900 specimens of naiads from the Wabash, Ohio, and Mississippi rivers and some of their tributaries in southern Illinois. An attempt was made to make a collection of all species now present in the rivers at the points of closest proximity to the Indian camp sites. By comparing the shell remains taken from such sites with species inhabiting nearby bodies of water, it is possible to obtain some idea of the abundance and species composition of past and present mussel populations. With a knowledge of the present habitat requirements of the various species now living, the similarities and differences between past and present populations can be better understood. Early climatic changes have been instrumental in effecting changes in population composition. Pollution has more recently had a significant influence on the abundance and the species composition of naiad populations in Illinois waters (Baker, 1922).

Baker (1923, 1930, 1931, 1937, 1941, 1951-52) was instrumental in identifying, in adding to the general knowledge, and in pointing out the significance of mollusk remains

TABLE 1.—The Numbers and Species of Naiads Removed from Eight Indian Sites in Southern Illinois.

Species	Modoc Rock Shelter (Mississippi River)	Fountain Bluff (Mississippi River)	Peter's Cave (Big Kinkaid Creek)	Blairsville (Big Muddy River)	Nigger Springs (Saline River)	Rosiclare (Ohio River)	Hubele (Ohio River)	Wilson (Ohio River)	Totals
Amblema peruviana (Blue-point)	136	2	14	13	145	. . .	1	4	315
Quadrula spp.	53	. . .	. . .	4	2	. . .	. . .	. . .	59
Uniomerus tetralasmus	52	1	. . .	. . .	. . .	. . .	. . .	. . .	53
Quadrula nodulata (Warty-back)	50	. . .	. . .	. . .	. . .	1	. . .	2	53
Quadrula quadrula (Mapleleaf)	37	. . .	3	2	9	. . .	. . .	. . .	51
Obliquaria reflexa (Three-horned warty-back)	32	. . .	. . .	. . .	4	5	. . .	1	42
Lampsilis ventricosa (Pocketbook)	28	1	17	. . .	2	1	. . .	. . .	49
Amblema spp. (Three-ridge; Blue-point)	27	4	42	20	29	. . .	. . .	1	123
Lampsilis anodontoides (Yellow sandshell)	18	. . .	. . .	. . .	27	2	. . .	. . .	47
Obovaria olivaria (Hickory nut)	12	. . .	. . .	. . .	. . .	3	. . .	1	16
Amblema costata (Three-ridge)	16	7	180	43	. . .	. . .	. . .	. . .	246
Elliptio dilatatus (Spike; Lady finger)	13	. . .	. . .	4	30	48	5	9	109
Quadrula pustulosa (Pimple-back)	9	. . .	2	6	23	16	3	5	64
Tritogonia verrucosa (Buckhorn)	9	. . .	2	2	6	. . .	. . .	1	20
Truncilla truncata (Deer toe)	9	. . .	. . .	. . .	. . .	. . .	. . .	. . .	9
Lampsilis spp.	7	. . .	16	. . .	. . .	. . .	. . .	. . .	23
Sphaerium sp. (Fingernail clam)	6	. . .	. . .	. . .	. . .	. . .	. . .	. . .	6
Fusconaia ebenus (Niggerhead)	5	. . .	. . .	. . .	37	83	4	4	133
Anodonta spp. (Floater)	5	3	8	. . .	1	. . .	. . .	. . .	17
Proptera alata (Pink heel-splitter)	4	1	3	. . .	. . .	2	. . .	. . .	10
Lasmigona complinata (White heel-splitter)	3	. . .	. . .	. . .	1	. . .	. . .	. . .	4
Megalonaias gigantea (Washboard)	3	1	. . .	1	. . .	1	. . .	. . .	6
Fusconaia flava (Wabash pigtoe)	3	. . .	126	. . .	. . .	. . .	. . .	. . .	129
Ligumia recta (Black sandshell)	2	. . .	. . .	. . .	3	. . .	1	. . .	6
Proptera sp.	2	. . .	. . .	. . .	. . .	. . .	. . .	. . .	2
Lampsilis siliquoidea (Fat mucket)	1	. . .	88	. . .	13	1	. . .	. . .	103
Micromya iris (Rainbow-shell)	1	. . .	. . .	1	. . .	. . .	. . .	. . .	2
Anodontoides ferussacianus (Cylindrical paper shell)	1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	1
Acridens confragosus (Rock pocketbook)	1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	1
Lasmigona compressa	1	. . .	. . .	1	. . .	. . .	. . .	. . .	2
Plethobasus cyphyus (Bullhead)	1	. . .	. . .	. . .	6	4	. . .	. . .	11
Fusconaia undata (Pigtoe)	. . .	. . .	12	16	41	4	1	1	75
Pleurobema cordatum (Small niggerhead)	. . .	. . .	. . .	. . .	29	37	3	1	70
Elliptio spp.	. . .	. . .	. . .	. . .	8	. . .	. . .	1	9
Elliptio crassidens (Elephant's ear)	. . .	. . .	. . .	. . .	6	. . .	. . .	1	7
Cyclonaias tuberculata (Purple pimple-back)	. . .	. . .	. . .	. . .	5	12	. . .	2	19
Quadrula metanevra (Monkey-face)	. . .	. . .	. . .	. . .	3	2	. . .	1	6
Plagiola lineolata (Butterfly)	. . .	. . .	. . .	. . .	3	5	2	. . .	10
Obovaria retusa	. . .	. . .	. . .	. . .	2	4	1	. . .	7
Anodonta grandis (Floater)	. . .	. . .	1	1	. . .	. . .	. . .	. . .	2
Anodonta imbecillis (Paper pond shell)	. . .	. . .	4	. . .	. . .	. . .	. . .	. . .	4
Lampsilis fallaciosa (Slough sandshell)	. . .	2	2	. . .	. . .	. . .	. . .	. . .	4
Ligumia subrostrata	. . .	1	. . .	. . .	. . .	1	. . .	. . .	2
Quadrula cylindrica (Rabbitsfoot)	. . .	. . .	. . .	. . .	. . .	3	. . .	. . .	3
Actinonaias carinata (Mucket)	. . .	. . .	. . .	. . .	. . .	1	1	2	4
Totals	347	23	520	114	435	236	22	37	1934

found in sites occupied by prehistoric Illinois Indians. Most of the published accounts of materials removed from such sites are limited to a qualitative listing of species encountered. However, Matteson (1953), in listing the numbers as well as the species excavated from a Hopewellian site in Morgan County, Illinois, provided information concerning the relative abundance some 500 years B.C. of the local naiad population in that area.

The accounts of species of mollusks, with a comparison of present living fauna, concern primarily those species constituting a major percentage of the total number of remains found. Mussels encountered at the Nigger Springs Site, Gallatin County, were obtained by the Indians probably from the Saline River (which flows within approximately 200 yards of the site) and possibly, although unlikely, from the Ohio River about 8 miles to the east. Indians occupying the Modoc Rock Shelter Site in Randolph County collected their mussels from the Mississippi River and its backwaters, now approximately two miles to the west (the river flowed considerably closer to this site during its period of occupancy). Mussels found at Peter's Cave were likely obtained from the Big Kinkaid Creek, while those from the Rosiclare Site seemingly came from the Ohio River.

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Discussion of Species

Amblema peruviana. — This was the most numerous mussel encountered at the Nigger Springs and Modoc Rock Shelter sites, and it constituted a large percentage of the total number in both sites. Today it is one of the most abundant species found in large and medium-sized rivers in central and southern Illinois. Valves of *Amblema costata*, a mussel typical of small to medium-size streams and rivers, formed approximately 73% of the total number of shells removed from the Peter's Cave Site. Big Kinkaid Creek evidently supported a large population of mussels at the time Peter's Cave was occupied, although now this relatively small creek is almost devoid of naiads. The large number of valves of *Fusconaia flava* and *Lampsilis siliquoidea* found at this site, species typical of medium-sized rivers, testify to their former abundance.

Quadrula spp. — Species of this genus, particularly *Q. quadrula*, *Q. pustulosa* and *Q. nodulata*, were fairly well represented numerically at the Nigger Springs and Modoc Rock Shelter sites. These mussels may

be found in a variety of aquatic habitats, but they apparently become especially numerous in the medium and larger rivers. As evidenced from the remains at these two sites, the "Warty-backs" and "Pimple-backs" were abundant in prehistoric times. Although *Q. metanevra* is common in the Mississippi, Wabash, and Ohio rivers today, it is rare compared to the other mussels found in kitchen midden refuse from sites along these rivers.

Fusconaia spp.—Goodrich and van der Schalie (1944:307), in referring to *F. undata*, considered its range primarily in the larger portions of rivers, while *F. ebenus* ". . . is a species found only in streams of considerable size and is never associated with a creek or small river environment". The abundance of these two species at the Nigger Springs Site seems to indicate that either the Saline River was considerably deeper than at present or that pollution has eliminated these species. Only one valve of *F. undata* and no specimens of *F. ebenus* and the Small Niggerhead (*Pleurobema cordatum*), another abundant species at the Nigger Springs Site, were found in the Saline River and its tributaries. *F. ebenus* is an abundant mussel in the Ohio and Mississippi rivers and as indicated by the quantity of valves found in midden refuse from the Rosiclare Site, the Snyder Site (a recently excavated Hopewell Site in Calhoun County) and others (Matteson, 1953), this mussel was abundant and widely used by the Indians.

Elliptio dilatatus.—The Spike is a common species in the lower Ohio River and it was taken in considerable numbers by Indians camping along its shores. Baker (1941) found this mussel to be one of the most abundant in pits and mounds excavated along the Illinois and Mississippi rivers in the northern half of the state. It was comparatively uncommon at the Modoc Site and according to van der Schalie and van der Schalie (1950) it is presently limited only to the upper regions of the Mississippi River. Although *E. crassidens* was fairly numerous in the Starved Rock middens (upper Illinois River in northern Illinois; LaSalle Co.) and in other sites of a corresponding time period (Baker, 1941; *et al.*) and is a common species today in the lower Ohio River, it is rare in sites in southeastern Illinois.

Lampsilis spp. — *L. fallaciosa* is abundant and wide-spread in a variety of habitats in southern Illinois, while *L. anodontoides* is now restricted more to the larger rivers and in local populations. Baker (1941) found the latter species rare in midden material examined by him, although the Slough Sand Shell was fairly abundant, possibly because it was more easily obtainable in shallower water. Valves of both species were numerous at the Nigger Springs Site, although *L. fallaciosa* is the one now inhabiting the Saline River. It, like *Amblema peruviana* and *Quadrula quadrula*, appears more tolerant of silting and pollution, while other species of *Lampsilis*, *Quadrula* and *Fusconaia* are unable to survive in such conditions.

Remains of *Lampsilis ventricosa*, another species fairly common in most streams and rivers throughout southern Illinois today, were relatively few in the Modoc and Peter's

Cave sites and rare or absent in the other sites. Baker (1941:60) stated that "This large mussel was more or less abundant in all mounds and sites" (material based on 10 major sites from LaSalle County southward to Jackson County). As in the case of certain other species (*i.e., M. gigantea*) that are common today but rare or absent from midden refuse, the relatively few valves of the Pocketbook found in Indian sites in southern Illinois may possibly be explained as the result of then smaller populations, very local populations, or perhaps preference on the part of the Indian.

Uniomerus tetralasums. — The presence of numerous shells (primarily fragments, particularly the umbo) of this species at the Modoc Site is of special interest since it tends to indicate that the Indian hunted for naiads in the shallow backwaters and sloughs as well as in the main river. It is a species typical of shallow, mud-bottomed ponds and sloughs, and it is widely distributed in such habitats in southern Illinois, but usually in small numbers. Apparently it, as well as *Obliquaria reflexa* and *Obovaria olivaria*, has been previously unreported from Indian camp sites in Illinois.

General Discussion

Because it was possible to enumerate the species of mussels encountered in the Modoc Rock Shelter and other sites, a relative correlation could be made of species abundance and composition between populations occurring in prehistoric times and those now inhabiting the rivers flowing in close proximity to these sites. Two factors that would decidedly influence this correlation are that of preference by the Indians and availability to them of certain species. It is within reason to assume that, over a period of time, availability would be the most influencing factor determining which species were collected. However, with the occasional presence of fairly numerous remains of relatively small species such as *Truncilla truncata* and *Obliquaria reflexa*, and the absence or rarity of certain common, large and meaty species such as *Lampsilis anodontoides* and *Megalonaias gigantea*, there is an indication that the Indian may have preferred one species over another.

An additional factor to be considered is the influence of weathering (when the shells are exposed) and/or erosion in the breakdown and eventual destruction of the clam or mussel shell. Although many species possess a thick shell which is generally very resistant to erosion and other destroying elements, some are quite thin-shelled and easily broken. Remains of these thin-shelled species are quite rare or entirely absent in midden refuse from Illinois sites. Of particular interest in this respect are the "Floaters" (*Anodonta* spp.), a group of generally thin-shelled, quite common and widely distributed species. Specimens of this genus were poorly represented in the shell remains reported by Baker (1941) and were entirely absent in the midden material examined by Matteson (1953). However, several fragments (umbo and the edentulous hinge line, as well as entire valves) of *Anodonta grandis* and *A. imbecillis* were encountered in five of the eight sites

considered here. The presence of these thin-shelled species would indicate their use by the Indian, although they may have been rejected in preference to certain other species.

Proptera alata was found "sparingly" at several sites by Baker (1941), and only a few fragments were encountered in the midden remains from four southern Illinois sites. Today it is an abundant species locally in the Mississippi and several of the smaller rivers of southern Illinois. Based on the comparative number of remains found, this naiad was possibly rejected in most cases as a food by the Indian. *Lasmigona complinata* is another very common, fairly thick-shelled mussel inhabiting lakes, streams and rivers throughout much of Illinois. Either this species was uncommon in prehistoric times or it was also rejected as food by the Indian, since remains of the White Heel-splitter are quite rare in kitchen midden refuse. It was identified from a site in Tazewell County (Fowler, 1952), and a single fragment was found in a Fulton County site (Baker, 1941). A single fragment was encountered at the Nigger Springs Site and three at the Modoc Rock Shelter (the fragments consisted of only the beak with the typical 4-5 heavy, looped bar sculpture).

The naiads listed from the Clear Lake Site in Tazewell and Mason counties (Fowler, 1952) include apparently the only record of *Leptodea fragilis*, the Fragile Paper Shell, from kitchen midden refuse in Illinois sites. Both it and the Purple Paper Shell (*L. laevissima*) are quite common in Illinois waters today, and again the question arises as to whether a particular mussel was simply rejected by the Indian. Quite possibly some of the generally thin-shelled species such as *Anodonta* spp., *Leptodea fragilis* and *L. laevissima*, *Lasmigona complinata*, and *Proptera alata* have increased in numbers and have become more widely distributed due perhaps to changes in water depth and bottom composition favorable to them.

The occurrence of *Obovaria retusa* in the Nigger Springs Site (two small valves), Rosiclare (four valves), Hubele (one valve), and in a Hopewellian mound in Hardin County (one moderately large valve) excavated by the Illinois State Museum in the summer of 1954 apparently represents the first records of this species in Illinois sites. It inhabits large rivers and is known from the Wabash and Ohio rivers in Illinois, although it is now uncommon to rare. The absence of *Megalonaias gigantea* from Nigger Springs and other sites is somewhat surprising and rather difficult to explain. Only three specimens were encountered from the Modoc Rock Shelter, and but one each in the Fountain Bluff, Blairsville and Rosiclare sites. This species is a common mussel and Baker (1944:57) stated that it "was extensively used by the prehistoric Indians of Illinois".

Summary

Shell remains from the mounds and camp sites of early Indian cultures in Illinois have made it possible to approximate the species composition and proportionate abundance of early populations of mussels in the Mississippi, Saline and other rivers in southern Illinois. As

was pointed out earlier in this paper, the presence of certain species and absence of others in kitchen midden refuse of sites in Illinois would tend to indicate that the Indian may have preferred certain species over others. However, availability was in all probability the major factor in a selection of the different species for food. Thus, by tabulating the numbers of each species present, it may be possible to obtain a relatively accurate estimate of the relative abundance of each as well as the species composition.

Exceptions to this generalization are to be expected, possibly in the case of *Lasmigona complinata*, for example. The presence of such forms as the Fingernail clam (*Sphaerium* spp.) and other species that are found rarely and only occasionally may possibly be explained on the basis of being "taken incidentally with other species" or bartered. The absence of a particular species from a site does not necessarily mean it was not inhabiting the stream or river at the time the site was occupied. Comparisons with shell remains from other sites aid in establishing the presence or absence of a given species in an area or river system during a corresponding time period. A good example of this is *Megalonaias gigantea*, a species commonly found today and remains of which were numerous in other sites, although no specimens were encountered in the test pits and surface collections made at the Nigger Springs Site. Possibly it was rejected by the Indians or perhaps it was uncommon to rare in the Saline River at that time. A total of only six valves was found in the midden materials from these eight sites.

It is logical to assume that the Saline River furnished most of the naiads used by the Indians occupying the Nigger Springs Site, although possibly (but not probably) some may have been transported from the Wabash or Ohio rivers. Pollution, probably coupled with silting and a lowered water level, has drastically affected the naiad complex of today, as compared with prehistoric times. This may be illustrated by reduced numbers or complete absence of such species as *Elliptio dilatatus, E. crassidens, Fusconaia ebenus, F. undata, Cyclonaias tuberculata, Plagiola lineolata*, and *Pleurobema cordatum* from the Saline River system today.

It becomes evident that the smaller streams and rivers such as Big Kinkaid Creek and the Saline River, which were apparently more completely and drastically affected by changes brought about by an altered course, pollution, silting, etc., underwent a more radical change in their faunal composition than did the big rivers such as the Wabash, Ohio, and Mississippi. More detailed examinations and analyses of faunal remains from Indian sites in Illinois in the future will add materially to our knowledge of the various Indian cultures and the effect of a changing climate on the fauna. In addition, they will provide more exacting information on the distribution, abundance, and species composition of many groups of animals living in Illinois during prehistoric times.

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THE BEAVER IN ILLINOIS

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Though beaver were once thought to have been permanently denied a place among the wildlife of Illinois, by 1946 they were again common enough to require considerable attention. Land owners were demanding that certain bothersome beaver colonies be controlled. Thus, in the fall and winter of 1946-47, game biologist Clayton C. Swears initiated investigations of troublesome beaver and live-trapped and transplanted the animals, where warranted.

At the time, the need for an appraisal and compilation of suitable points of release for beaver was apparent. In addition, there were no accurate data on populations and distribution of beavers. To fill these needs, the Illinois Natural History Survey and Illinois Department of Conservation entered into cooperative beaver research as of April 1, 1947. They established Federal Aid Project No. 33-R under terms of the Federal Aid in Wildlife Restoration Act. This paper is based upon the findings of Project No. 33-R, the Illinois Department of Conservation, the United States Fish and Wildlife Service, and the Illinois Natural History Survey, cooperating. The project was terminated June 30, 1951.

Acknowledgments

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Early Status of Beaver in Illinois

When white man first came to Illinois, beaver were widely distributed in the state. Cory (1912:161) wrote, "In early days Beavers were common along the wooded streams throughout Illinois." Apparently their numbers remained high in Illinois until about the time of the arrival of permanent settlers. Cory (1912:162) reported, "They were common in suitable localities throughout the state in the early part of the last century." Similarly, James (1823:44), in referring to the land above the confluence of the

Mississippi and Ohio rivers, wrote, "Deer, turkies, and beaver, are still found in plenty in the low grounds, along both sides of the Mississippi."

Wood (1910) reported that beaver remained abundant in Champaign County until the early eighteen hundreds. His chart on beaver abundance indicated that from about 1835 to about 1857 beaver were rare in Champaign County. Apparently the last ones were seen in the vicinity of Broadlands in 1860.

It is believed that excessive trapping brought about the downfall of beaver in Illinois. The beaver population apparently declined very sharply and with gathered momentum. Brown and Yeager (1943:489) wrote, "The beaver has been of no appreciable importance in the Illinois fur trade since about 1850." Kennicott (1885:579), in writing about animals of Cook County in the mid-eighteen hundreds, stated, "The remains of beaver dams exist in several streams." Thomas (1861: 657) felt, "That any individuals of this species now exist in this State is doubtful, yet possible."

Remnant beaver colonies did exist in Illinois for several decades hence. Cory (1912:161) disclosed that, "Mr. B. T. Gault of Glen Ellyn, Illinois, wrote me that in the year 1900 he saw some Beaver cuttings near Thebes, Alexander County in Southern Illinois;". In the same year Forbes (1912:47) wrote, "The beaver is reported from four Ohio River counties". Unfortunately he failed to name the counties. But in a more recent publication, Mohr (1943) indicated that beaver were last recorded in 1912 in Bureau, Massac, Pulaski and Williamson counties.

Releases of Beavers

The U. S. Fish and Wildlife Service assisted with the return of beaver to Illinois when Albert Cheney and Harley Lawrence released an adult male and female on the Savanna Proving Grounds in Jo Daviess and Carroll counties on May 11, 1929. Subsequent observations indicated that these beavers moved northward along the Mississippi River and beaver sign was light for the following four or five years. Sergeant Albert Bingham (U. S. Army, retired) reported, in a personal interview on May 22, that 16 more beavers were released on the same proving grounds in the spring of 1936.

The U. S. Forest Service made releases in 1935. During November of that year, 19 beavers were released in Pope County—10 in Hunting Branch, a tributary of Bay Creek, and 9 in Grand Pierre Creek (Mohr, 1943). Adams (1936) indicated that these animals were obtained from Woodruff, Wisconsin. Two beavers were released at the East St. Louis Hunting Club near Reynoldsville, Union County, on March 1, 1936 (Mohr, 1943). A release of four beavers obtained from the Wisconsin Department of Conservation, was made in August, 1936, in Rosedale Township, Jersey County (Thatcher, 1937).

The last reintroduced beavers, one male and two females, were obtained by the Illinois Department of Conservation in October, 1938. These animals were released in the La Rue Bottoms in Union County (Mohr, 1943).

In addition to these early releases, emigrations from neighboring states may have contributed importantly

to the present distribution of beavers in Illinois. George J. Knudsen of the Wisconsin Conservation Department indicated (pers. letter, October 26, 1954) that according to old-time trappers in Grand and Crawford counties in Wisconsin, there always have been a few beavers in the Mississippi River bordering on these counties. Grant County is adjacent to Jo Daviess County, in Illinois.

Releases in eastern Iowa probably influenced the return of beavers to western and northwestern Illinois. John Madson (pers. letter, March 4, 1955) of the Iowa Conservation Commission wrote, "Stocking in eastern Iowa counties began in 1940, but, it was necessary to begin nuisance trapping in some of these counties by 1943." He reported the following releases: in 1940, four beavers were released in Jackson County and three in Muscatine County; and in 1941, 23 beavers were turned loose in Muscatine County and 4 in Lee County. Jackson County borders on Jo Daviess and Carroll counties in Illinois. Muscatine County is across the Mississippi River from Illinois' Rock Island County. Lee County faces Hancock and Henderson counties in Illinois.

In reporting on Missouri furbearers, Bennitt and Nagle (1937:139) stated that, "According to information received in 1937 and 1936 . . . they have extended their range down the Meramec River into St. Louis County." St. Louis County is across the Mississippi River from Madison and St. Clair counties in Illinois.

John M. Allen of the Indiana Department of Conservation (pers. letter, January 31, 1955) quoted from the 1939 Annual Report of the Indiana Department of Conservation as follows: " 'Beavers are continuing to expand their territory since the first restocking of these was made in 1935 in Jasper, Pulaski and Starke Counties, and now can be found in a dozen counties in the northern part of Indiana.' " Jasper, Pulaski and Starke counties are in northwestern Indiana. Allen continued in his letter: "Not all of the release sites are known but some were made on the Kankakee State Game Preserve and others on the Jasper-Pulaski State Game Preserve, both of which are on or near the Kankakee River." Emigrations down the Kankakee River into Illinois' Kankakee County may have occurred several years after Indiana's first release in 1935.

Recent Trends in Population and Distribution

The success of releases in the Shawnee National Forest in southern Illinois was described by Mohr (1943:434): "They numbered only 19 in December, 1935, and 25 in 1937, according to U. S. National Forest estimates of furbearing animals in national forests." He reported the total estimated population in 1939 as 48. Bonnell (1941) suggested a beaver population of about 70 in the Shawnee National Forest in 1940.

In a U. S. Forest Service mimeographed report (February 17, 1947) Herman F. Olson gave an account of the beaver in the La Rue Bottoms in Union County. In February, 1947, there were eight active beaver houses. By assuming an average of

5 beavers per house, he arrived at a total population of 40 beavers.

Some data on distribution were obtained for Illinois in the spring of 1947. Conservation officers in all 102 counties in the state were asked to report on the status of beavers in their respective counties. Nineteen of the 81 that replied reported beavers present in their counties.

Complete returns were obtained from questionnaires sent to conservation officers in the falls of 1949 and 1950. Beavers were reported present in 34 counties in 1949 and 45 counties in 1950. The officers estimated state totals of 521 colonies in 1949 and 713 colonies in 1950. If an average of five beavers per colony is assumed, the estimated 1949 beaver population was 2,605 and the 1950 population was 3,565.

Returns of a questionnaire sent to conservation officers in the fall of 1954 showed that beavers had spread to 55 counties (Fig. 1). Indications were that beavers were still not found in a block of 22 counties in southeastern Illinois and in a block of 9 counties in the northeastern part of the state.

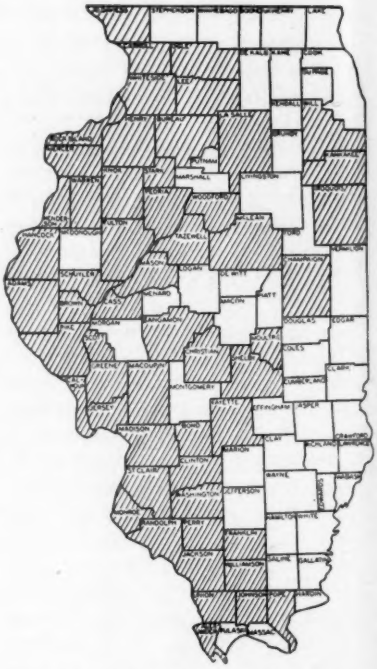

FIG. 1.—Counties in which beavers were reported present in 1954.

COMPLAINTS OF DAMAGES BY BEAVERS

By 1945, beavers had become well established in many parts of the state. Damages by beavers were reported from several counties. In 1946 the Illinois Natural History Survey and Illinois Department of Conservation assigned Clayton C. Swears to investigate complaints of beaver damage and to take corrective action short of killing the beavers.

From the fall of 1946 through the spring of 1948, Swears investigated 12 beaver colonies. He felt that the damage or potential damage by beavers in 11 of the 12 cases was such that the landowners involved were entitled to some assistance from the state. It was thought that the troublesome animals would leave if their dams were destroyed. Experience revealed that this was usually not true. Live-trapping and transplanting ordinarily proved only partially successful. It was usually easy to catch one or two members of a beaver colony, but it was very difficult to capture the entire family.

Others charged with the responsibility of investigating complaints

TABLE 1.—Compilation of Investigations of Troublesome Beavers, 1946 Through 1951.

Year of investigations	No. colonies investigated	No. valid complaints
1946	1	1
1947	5	4
1948	16	12
1949	24	19
1950	5	4
1951	2	2
Total	53	42

about beavers were Kenneth W. Dodd in 1948, the author in 1948 and 1949, and Edward A. Fitzgerald in 1949, 1950, and 1951. During the course of these inspections, records were kept on 53 beaver colonies.

It was determined that 42 of the 53 (79.2%) beaver colonies examined from 1946 through 1951 were incompatible or potentially incompatible with man's interests. A breakdown of the valid complaints about beavers is given in Table 2.

The data in Table 2 indicate that most landowners who report beaver damages are concerned about crop losses. Destruction of valuable timber and damages to levees appear to be far less important. The complaints include the following: flooded livestock crossings, potential highway flooding, damage to ornamental trees and shrubs, and burrowing into farm pond dams.

TRAPPING AND TRANSPLANTING

Clayton Swears made his first beaver catch on November 26, 1946. Subsequently, Swears, other personnel of the Department of Conservation and U. S. Forest Service, trapping until the fall of 1951, caught

TABLE 2.—Classification of Colonies of Destructive Beavers Examined, 1946 Through 1951.

Year investigated	Number of beaver colonies involved in damages to:			
	crops	levees	timber	miscellaneous
1946	1	..	..	..
1947	2	1	1	..
1948	9	1	..	2
1949	14	1	2	2
1950	..	3	..	1
1951	..	1	..	1
Total	26	7	3	6

TABLE 3.—Beavers, Live-trapped in Illinois, 1946 Through 1951.

Year trapped	County where trapped									Total annual catch
	Lee	Union	Henderson	Johnson	Jo Daviess	Carroll	Whiteside	Knox	Warren	
1946.....	4	..	..	..	..	..	..	..	..	4
1947.....	..	4	..	..	..	..	..	..	..	4
1948.....	5	20	2	7	..	..	..	..	..	34
1949.....	5	..	6	..	6	4	12	6	3	42
1950.....	..	8	..	..	..	..	..	..	..	8
1951.....	..	3	..	..	1	..	2	..	..	6
Total....	14	35	8	7	7	4	14	6	3	98

98 beavers. Ten of these died from trapping and handling; the remainder were transplanted in Illinois.

Only four beavers were captured in 1946; in 1949, 42 beavers were taken. Notwithstanding this increased catch, Department of Conservation officials were unable to cope with the incessant flood of complaints about beavers. Further, suitable vacant release points were not available. As a last resort, in late 1949, 1950 and 1951, releases were made in areas in the state where beaver already existed, but where they did not interfere with the activities of man.

HARVESTS OF BEAVERS

In the summer of 1951 the Illinois legislature provided for an open season on beavers from December 1 to 15. This established the first open season on beavers ever provided for by the Illinois law makers. The act required that each prospective beaver trapper buy a special $5.00 license. Each trapper was limited to 10 beavers per season and a special $2.00 tag was required for each pelt prior to sale.

According to the number of pelt tags sold, the 1951 catch totaled 659. These tags were issued in 44 counties (Fig. 2). It was thought that the number of beaver pelt tags sold might reflect the take in those counties; however, in Cook County 11 pelt tags were issued but beaver colonies were not known to exist in that county at the time.

The pelt tags sold in 10 counties accounted for 445 beavers or 67.5% of the total catch. It is noteworthy that the largest number of tags was sold in Jo Daviess, Carroll, and Union counties. A large release was made in 1936 on the grounds of the Savanna Ordinance Depot in Carroll County, the next county south of Jo Daviess County. In addition, it was very likely that beavers emigrated into these counties from adjacent counties in Iowa and Wisconsin. The large sale of tags in Union County probably was correlated with the large beaver population in the

TABLE 4.—Beaver Releases by Counties in Illinois, 1946 Through 1951.

Year released	County where released													Total annual release
	Fulton	Jackson	Union	Fayette	Bureau	Henderson	Franklin	Pope	Mason	Calhoun	Whiteside	St. Clair	Lee	
1946.....	2	..	..	..	..	..	..	..	..	..	..	..	..	2
1947.....	..	4	..	..	..	..	..	..	..	..	..	..	..	4
1948.....	7	..	13[1]	3	1	1	2	7	..	..	..	..	..	34
1949.....	..	..	..	..	..	4	..	..	14	13	1	2	..	34
1950.....	..	..	8	..	..	..	..	..	..	..	..	..	..	8
1951.....	..	..	..	..	..	..	..	..	..	5	..	..	1	6
Total..	9	4	21	3	1	5	2	7	14	18	1	2	1	88

[1] An unknown number of these 13 were released in Monroe County in 1948.

La Rue Bottoms resulting from the release there in 1938 and from favorable habitat.

Only two pelt tags were issued in Pope County. The initial reintroductions of 19 beavers were made in Pope County in 1935. This relatively low sale of tags suggested that beavers did not settle here as readily as in some of the other counties. Some of the Pope County beavers may have migrated to adjacent Johnson County, because 29 tags were issued there.

Trappers took 516 beavers during the beaver season in December, 1952. This catch was 143 less than the 1951 harvest. Field observations indicated that the beaver population in 1952 was at least as large or larger than the population of 1951, and many of the trappers had one season's experience. It was expected that this would have resulted in as large a harvest in 1952 as that of 1951. Trapping pressure declined in 1952 as a consequence of: 1) high costs of the special beaver license, pelt tags, and traps; 2) the unexpected difficulty in trapping, skinning, and fleshing beaver; and 3) the low return for beaver pelts the previous year. A leading buyer of Illinois furs disclosed that the average price paid for beaver pelts caught in Illinois during the 1951-52 season was $7.48.

To encourage a more complete harvest of the surplus beavers, the taking of beavers on the regular furbearer license and a pelt tag fee of 50 cents were provided for in 1952. Further, an open season on beavers from February 1 to 15 was allowed. The pelts were known to be more prime in February than in December; thus, it was thought that the pelts would yield greater returns.

Yet the catch in February, 1954, was only 332, down 184 from the previous season's catch! In spite of this low catch, field observations and reports indicated that the 1954 statewide population of beavers was higher than that of the year before. The following reasons were advanced

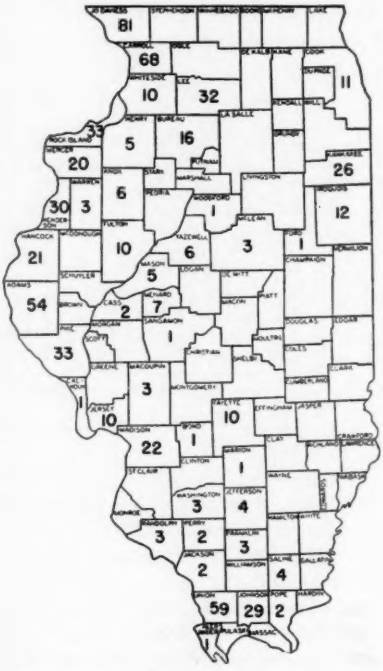

FIG. 2.—The number and location of beaver pelts taken legally in 1951.

for the smaller catch in 1954: 1) only beavers could be taken in February; thus, the added incentive of catching other valuable furbearers in conjunction with beavers was non-existent; 2) the difficulty of trapping and handling beavers was discouraging; and 3) the return for pelts was still low. The average price declined to $4.47 for the 1952-53 season. This same source revealed that beavers taken in Illinois during the 1953-54 season returned an average of $5.43 per pelt.

The sale of beaver pelt tags in 1955 indicated that the catch in February of this year was only 250. Paradoxically, during the last four years, the beaver population in Illinois seemed to be increasing, yet the annual catch continued to decline.

SUMMARY

When white man first came to Illinois, beavers were common along wooded streams throughout the state. Beavers were last reported from Bureau, Massac, Pulaski, and Williamson counties in 1912. They were not again reported from Illinois until they were reintroduced in 1929. Recorded releases from 1929 through 1938 totaled 46 animals in 4 counties. In addition to these early releases, emigrations from neighboring states may have contributed to the present distribution of beavers in Illinois.

Conservation officers reported that beavers were present in 34 counties in 1949, in 45 counties in 1950, and in 55 counties in 1955. The 1949 beaver population was estimated at 2,605 animals. In 1950 the population was calculated at 3,565.

From 1946 through 1951, 53 complaints of beaver damage were investigated. Damages to crops were involved most frequently. Ninety-eight beavers were live-trapped and relocated in 13 counties.

Contrary to the interests of good husbandry, the harvest of beavers for fur has been declining, while the beaver population continues to increase. In the December, 1951, beaver season, 659 beavers were taken in Illinois. In December, 1952, 516 were caught; in February, 1954, the catch was 332; and in February, 1955, the catch was only 250.

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COLLEGIATE

SUBURBANIZATION OF A RURAL TRADING CENTER

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The great variability of urban life in time and space is ample evidence that the kinds of cities we live in depend on many determinants, of which *function* is by no means the least important one. All urban settlements exist to serve one or more purposes. These may be economic, political, cultural, recreational, residential, or a combination of two or more of these.

Dormitory cities, essentially suburbs, are one of these distinct types. Their principal function is to provide living quarters, and they are located relatively near, in space or time, to the central city to which they are functionally related. The prestige and character of a particular residential suburb is dependent, generally, upon the political, economic, and social characteristics of its inhabitants.

Of late, small urban settlements, previously serving as rural service centers and located outside of standard metropolitan areas but relatively near large cities, have attracted the attention of geographers interested in urban phenomena. Generally, it has been assumed that the residents of these small rural service-centers work within the settlement or on farms immediately outside of it or that they are retired farmers or businessmen. For one reason or another, these former rural service-centers are becoming dormitory towns, and a large proportion of their population is no longer earning a livelihood within the center, but is commuting to work in nearby industrial cities. Such a settlement is Platteville in the unglaciated area of southwestern Wisconsin. This study was undertaken to discover reasons for the change in the primary function of this city from that of a rural service center to one of a residential suburb.

Method

Data on which the findings have been based were gathered by means of a stratified random sample drawn systematically, supplemented through personal interviews.

From field observations, it was judged reasonable that a 20% sample of the dwelling units of the entire city of Platteville would provide the necessary information. Dwelling units were selected as the best places at which to interview those residents of Platteville who make up the labor force. The sample was taken on August 15 and 29, 1955, and included 244 homes. On a randomly determined basis, the occupants of

every fifth dwelling unit were selected to be interviewed, beginning with the first dwelling unit on the southwest corner of a block and then going on to the sixth, eleventh and so on in counterclockwise manner around the block. If there were no response from the fifth dwelling unit, then it was arbitrarily decided that dwelling unit four would be taken. If there were still no response, then dwelling six would be included in the sample. The sample, therefore, was stratified to ensure coverage of the entire city and to include all laborers. It remained randomized to give adequate data for estimation of the parameter. In all, 230 employed persons were interviewed. Seven per cent of the total interviews were recorded as unsuccessful, no recalls being made.

Each interviewer was assigned to a particular segment of Platteville, and the following questions were asked: 1) where does each employed member of the dwelling unit work?; 2) what is the type of employment providing he or she works outside Platteville?; and 3) are there any retired people living in this dwelling unit providing no one living in the dwelling unit is working? Further questions included why people worked out of town, if they did, and how recently they had moved to Platteville, if they had not lived there all their life.

Personal interviews with businessmen of Platteville were also obtained.

Results

From the data tabulated it has been estimated that 31.7% of the labor force of Platteville commutes to work in Dubuque, Belmont, Cuba City, Dodgeville, Ellenboro, Lancaster, Tennyson, Waupam, or in Grant County generally. Those commuting to Dubuque form the largest group. Fifteen and eight-tenths per cent of the total who commute to work are travelling salesmen, and 9.7% are government workers.

It was also found that retired people lived in 17.6% of the dwelling units sampled. Considering the percentage who commute and those who are retired, the dormitory function of Platteville appears to involve approximately 50% of the adult population of the town.

The factors which account for the development of the dormitory function of Platteville were found to be four-fold: 1) transportation facilities; 2) job opportunities elsewhere; 3) tradition and family ties; and 4) other social conditions.

The recent development of all-year highways between Platteville and Dubuque and other towns and the increase in car ownership in Platteville were also found to be important factors in the decision to commute. Both decrease commuting time. In addition, several factories within Dubuque, in particular the John Deere Dubuque Tractor Works, now employ residents of Platteville.

Many commuters have lived in Platteville most of their lives. Their families are here and, because family living may be, or may be thought to be, more advantageous in a small community, many families continue to reside in one. Familism, the investment in the familial system of the society, was given by many as a reason why they lived in Platteville and commuted to work.

In addition, other social factors were found to be determinants in a worker's decision to live in Platteville. These include the small-town atmosphere, the personal contacts in contrast to the impersonal anonymity of living in a large industrial town, and the advantages of owning one's home. Entertainment in the form of television, radio, and easy access to the facilities in nearby larger cities were also indicated as being important. The isolation of the rural community the size of Platteville is no longer true. As a result, it has become attractive to those who do not care to live in the more crowded conditions in the larger industrial center of Dubuque.

Conclusions

This study showed that commuters form approximately three-tenths of the total labor force in Platteville, Wisconsin. It may be assumed that the main reason for seeking employment outside of the town is the scarcity of jobs in Platteville itself. If new opportunities for employment arise in Platteville, part of the commuting population would be locally employed. But a goodly share of the workers would still commute. Rural service-centers, located relatively near large industrial centers, are proving attractive to the industrial worker who can afford to travel by automobile each day to work. Thus, it appears that commuters will continue to comprise a sizable proportion of the labor force of Platteville, and the present trend toward a dormitory residential function will change the character of a once small rural service-center.

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NON-SAPONIFIABLES FROM DEEP-FRY FATS

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College of St. Francis, Joliet

The non-saponifiable fraction of various animal and vegetable fats used in deep-frying is largely composed of sterols related to the sitosterols. Since the preparation of deep-fried foods is carried out under oxidative high-temperature conditions, it is not inconceivable that these sterols might be dehydrogenated to aromatic polycyclic compounds related to the cholanthrenes which are known to be carcinogenic. With this in mind, a number of fats used in deep-frying were saponified with alcoholic potassium hydroxide solution, and the non-saponifiable fractions were extracted with benzene from the water-soluble soaps for preliminary biological screening.

MATERIALS

The fats were selected from several local restaurants and had been used in the deep-frying of the various foods indicated below. The composition of each fat, insofar as it was known, together with conditions of usage, are recorded as follows:

Fat 1.—A hydrogenated vegetable oil used to deep-fry meat, fish and potatoes at 150-200° C. for at least six months. Fresh oil was added as it was needed and occasionally the oil was filtered.

Fat 2.—A homogenized shortening of animal and vegetable oils in which shrimp and fish were deep-fried at 175-180° C., 17 hrs. per day for 10 days.

Fat 3.—A hydrogenated animal fat and vegetable oil used at 175° C. for chicken, potatoes and fish, 11 hrs. per day for 6 days.

Fat 4.—A homogenized shortening made from animal and vegetable oils in which shrimp was deep-fried at 175-180° C., 17 hrs. per day for 10 days.

Fat 5.—Same as No. 4 used for one month (17 hours/day) to deep-fry chicken and fish.

Fat 6.—Same as No. 4, used for one month (17 hours/day) to deep-fry potatoes.

Fat 7.—A cottonseed oil heated with aeration in our laboratory at 175° C. for 11 days, 24 hrs. per day. This product was exceedingly gummy and apparently had polymerized.

Fat 8.—An untreated corn oil used for control purposes. Crystalline sitosterols were obtained from this fat using the procedure outlined below.

TABLE 1.—Yields and Sterol Tests on Non-Saponifiable Extracts from Deep-Fry Fats.

Fat no.	Per-cent yield of non-saponifiable fraction	Lieberman-Burchard test
1.....	0.3	slightly positive
2.....	0.7	slightly positive
3.....	0.8	negative
4.....	1.2	slightly positive
5.....	0.7	slightly positive
6.....	0.6	slightly positive
7.....	1.3	negative
8.....	1.5	strongly positive

SAPONIFICATION AND ISOLATION PROCEDURE

Each sample of used fat (250 gms.) was refluxed with 500 ml. of 20% alcoholic potassium hydroxide solution for 5 hours. A portion of the alcohol was removed by distillation and the residual soap was diluted with three volumes of water. The solution was extracted 3 times with 500-ml. portions of benzene and the combined benzene extracts were washed with distilled water to remove traces of soap. The benzene was removed by distillation and the non-saponifiable concentrate was weighed and tested qualitatively for sterol content by the Lieberman-Burchard reaction. The yields of non-saponifiable material as well as the sterol tests are listed in Table 1.

SUMMARY

A variety of fats, commonly used in the deep-frying of foods such as potatoes, fish, and chicken, were saponified and the non-saponifiable fractions were isolated. From their non-crystalline appearance and the weakly positive Lieberman-Burchard tests it was apparent that the sterols present in the original fats had been altered during the deep-frying process. These non-saponifiable fractions are being screened for possible carcinogenic activity by Dr. Arthur Furst at Stanford University School of Medicine.

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ELECTRICAL CONDUCTIVITIES OF ISOMERIC BUTYL BROMIDES

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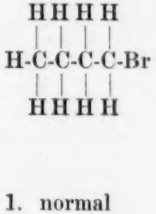
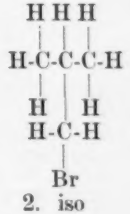
INTRODUCTION

Methyl groups are considered more electron-releasing than single hydrogen atoms. This means that the electron pair joining a methyl group to a given carbon is closer to that given carbon than is the electron pair joining a single hydrogen to the same given carbon. Such electron displacement can, to a degree, accumulate from several methyl groups and be transmitted along a carbon chain. If thus transmitted to a halogen atom, the electron displacement results in an increased tendency for the halogen to sever its connection and depart from the parent compound as an anion. (Desha, 1952: 43, 124).

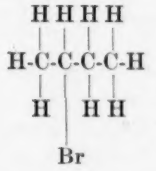
Four different isomeric butyl bromides exist — and their electrical conductivities should, from the foregoing considerations, increase in the order $1 < 2 < 3 < 4$. The experiments here reported were done to test this prediction.



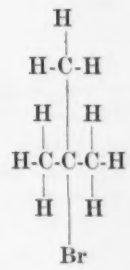
1. normal



2. iso



3. secondary



4. tertiary

APPARATUS

The apparatus of Sellers and Sulzbach (1955) slightly modified was used for measuring the conductivities of the butyl bromides. The fundamental parts of the modified setup are diagrammed in Figure 1. The organic liquid being tested is contained in an H-shaped glass cell *F*, between platinum electrodes. The battery *B* and travelling-plug resistance box *A* serve to deliver a definite fraction of the available potential difference, through *F* or bypassing it, according to the setting of switch *E*. The switch *D* allows the net resulting potential to be applied to the precision condenser *C*; *D* also may be set to let *C* discharge through the ballistic galvanometer *G* on depressing key *H*. *H* when released shunts *G* by a critical damping resistance

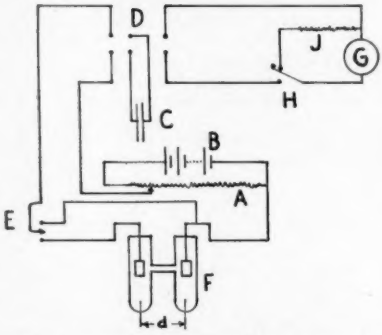


FIG. 1.—Wiring diagram of conductivity-measuring apparatus: *A*, potential divider; *B*, ten dry-cell batteries; *C*, condenser of known capacitance; *D*, short-throw double pole, double-throw switch; *E*, switch to by-pass H-cell; *F*, H-cell with platinum electrodes; *G*, ballistic galvanometer; and *H*, high-insulation contact key.

J, so as to stop *G* and make it ready for a new measurement in the minimum of time.

An air thermostat (with electric heating and circulation of air) and an electrical timer were employed.

The voltage of *B* must be great enough to send a small but definite current through *F*, sufficient to give a readable deflection of *G* in a reasonable time. The relation of *R* to *B* should be such that the square of the voltage divided by the ohmage never exceeds one-fourth watt.

The condenser used here was of 0.500 microfarads capacity, and the galvanometer had a sensitivity of about 10^{-9} coulombs per cm. deflection, *A* was 10,000 ohms, and *B* was sometimes as high as 15 volts. The thermostat temperature was 25.0 $\pm$ 0.5°C; the cell constant was 58.5. Wide variations in apparatus are permissible.

CHEMICALS

The four butyl bromides were prepared from corresponding alcohols according to methods of Adams and Johnson (1948: 199-201) and Gilman and Blatt (1951: 38-41) and purified until boiling points agreed well with those in the literature.

PROCEDURE

The sample was put in *F* in amount sufficient to fill the horizontal tube. The electrodes were installed centrally in their wells, with faces perpendicular to the axis of the horizontal tube, and centered upon it. The cell was put into the thermostat and allowed to reach temperature equilibrium. A voltage was provided at *A* sufficient to give through *F* a useful charge on *C* in 15.00 seconds, and allowed to act through *F* for this time interval. *C* was then discharged as punctually as possible through *G*, by manipulating *D* and *H*. The resulting deflection Θ was read. Then the process was repeated with *F* bypassed, and the voltage at *A* lowered, if necessary, by an aliquot fraction. The new deflection divided by the aliquot fraction (which might be unity) was recorded as Θ_0. The distance *d* between the electrodes in *F* was measured by simple sighting to a centimeter ruler. *F*'s cross-sectional path area *A* was determined from micrometer measurements upon a glass rod which slip-fitted inside a piece of tubing like the horizontal portion. From the capacity *c* of the condenser in farads, the time of charge *t* in seconds, the deflections Θ and Θ_0 in centimeters, and d/A in reciprocal centimeters, the specific

conductivity L of the sample was calculated. Formula a was used when Θ and Θ_0 were of the same magnitude and formula b otherwise.

$$(a)\quad L = 2.30\,\frac{cd}{At}\,\log_{10}\frac{\Theta_0}{\Theta_0 - \Theta}$$

$$(b)\quad L = \frac{cd}{At}\,\frac{\Theta}{\Theta_0}$$

Derivation of Working Equations

Smith (1948:59-60, 107-108) gave essential details. In summary, the fundamental circuit contains a voltage source, a resistance and a condenser in series. At any instant, the sum of the three voltages across these circuit elements adds up to zero, according to Kirchoff's second law of circuits. The resistance's voltage, by Ohm's law, is its resistance multiplied by the current through it; the condenser's voltage is the charge on it divided by its capacitance. The current may be replaced by rate of change of charge with time, and the resulting differential equation rearranged and integrated. The integration constant is evaluated from initial conditions; charge is zero when time is zero. The resistance is the reciprocal of the conductivity. The specific conductivity is the proportionality factor between measured conductivity and the ratio of path area to path length; the ratio d/A is the cell constant. Combining all these ideas leads to equation a. Equation b has been derived by us, by taking the natural-logarithm prototype of a and dividing out the fraction beyond the log symbol. The fraction is expressed as $1 + \frac{\Theta}{\Theta_0 - \Theta}$ thereby. Then the second term of the denominator is dropped, the natural-logarithmic sum expanded in a Maclaurin series, and all terms but the first dropped.

Results

These are shown in Table 1. Each number represents a mean of several closely-agreeing results, with checks by intervening repurifications.

Table 1.—Conductivity of Butyl Bromides.

	Θ_0	Θ	L
Normal butyl bromide	195.00	0.50	0.0050
Isobutyl bromide	194.00	0.80	0.0078
Secondary butyl bromide	195.00	44.50	0.502
Tertiary butyl bromide	194.50	2.95	0.0295

The secondary compound revealed no acid present when tested with moist litmus.

Interpretation

The order of specific conductivity therefore is $1 < 2 < 4 < 3$ instead of the predicted $1 < 2 < 3 < 4$. We tentatively assume that the remarkably high specific conductivity of the secondary compound is caused by the "electron suction" of one of the partly electron-emptied methyl groups which can approach the bromide. Only in the secondary compound can one methyl group approach the bromine at a place remote from its valence while more than one feed electrons at short range along the chain.

Acknowledgment

The apparatus used in this investigation was provided by The Research Corporation, New York, N.Y.

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Illinois Academy of Science Transactions, Vol. 49, 1956

BACTERIA WE DRINK

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Water is considered unsafe to drink without boiling when it contains bacteria that live naturally in the intestines of man or other warm-blooded animals, such as chickens, horses, cows, pigs, etc. These various intestinal bacteria are commonly referred to, collectively, as the coliform group. Fortunately, most of the coliform bacteria are not disease-producing bacteria. However, the fact that they are present in water indicates that an avenue of contamination is open for disease-causing bacteria to get into the water supply in the same manner that the coliform group gained entrance.

The coliform group of bacteria is considered more technically to include all aerobic and facultative anaerobic gram-negative, non-spore-forming bacilli which ferment lactose with gas formation. The genera most often encountered are *Escherichia* and *Aerobacter,* and they have become known as the indicators of pollution. Water is considered unsafe to drink without boiling or treating chemically when either or both are found.

The first step in a standard bacteriological water analysis as prescribed by the American Public Health Association is the inoculation of lactose broth fermentation tubes and is referred to as the "presumptive test" (Norton, 1946). If gas is formed in lactose broth, it is presumed that the coliform group is present, and the result is called a "positive presumptive". However, the "confirmed test", which requires the inoculation of a more selective medium than lactose, is necessary to prove that the coliform group is definitely present. Thus, it is not unusual to find water in which there are bacteria that ferment lactose to produce gas and then fail to produce gas in a confirmatory medium. Such a result is called a "false positive presumptive". Very little attention has been given to the organisms responsible for such results; therefore, it is with the occurrence and significance of the false positive presumptives in Charleston drinking water that the writers are primarily concerned.

Review of Literature

Advanced student projects by Jones (1948) and Loftin (1949) were concerned with the Charleston, Illinois, drinking water. The occurrence of false positive presumptives and the effect of pre-chlorination on the reduction of bacteria responsible for false positive presumptives were studied. Little or no attention was given to species determinations.

It is rather generally agreed that false positive presumptives may result from either of two possibilities.

First, species of the genera *Clostridium, Bacillus, Klebsiella, Erwinia,* and *Serratia* have been reported by Salle (1954:523-524) as being capable of fermenting lactose and then failing to produce a positive confirmation. Second, a type of biological association known as synergism, which involves the joint action of two or more organisms on a substance, has been known to result in lactose fermentation that produced gas but yet this same joint action would not ferment a confirmatory medium. The exploring of these two possibilities for an explanation of Charleston's drinking water problem was the major objective of this study.

Methods

Numerous water samples were collected at the filtration plant water intake in Lake Charleston and at various points throughout the city during September and October, 1955. Raw lake water was water which had no chemical treatment whatsoever. Drinking water samples had pre-chlorination, chemical treatment, sedimentation, filtration, and post-chlorination. Each sample was submitted to the presumptive and confirmed tests as prescribed (Norton *et al.,* 1946). Pure culture isolations were made from the nutrient agar dilution plates and were submitted to standard procedures for the identification of species (Breed, 1948).

Results

Of a total of 50 portions of raw lake water inoculated into lactose broth, 40 (80%) produced gas in the presumptive test. Thirty-nine (78%) of the presumptive portions confirmed the presence of coliform bacteria when inoculated into brilliant green bile. Thus, only 2% of all the raw lake water portions tested were found to be false positive presumptives (Table 1).

In chlorinated drinking water only 5 (4%) of the 125 portions inoculated into lactose were found presumptive. None of the positive presumptive portions produced gas in the confirmed test. Thus, all of the portions found presumptive in chlorinated drinking water were false positive presumptives (Table 1).

This relationship of low percentage values for false positive presumptives in Charleston's raw lake water and chlorinated drinking water has not always existed. Jones (1948) reported 74% of all chlorinated drinking water tested as false positive presumptives. Following the adoption of pre-chlorination, Loftin (1949) reported less than 9% false positive presumptives. The Lipousky (1955) data (Table 1) show only 4% of all drinking water portions as false positive presumptives. This evidence seems to support the suggestion that the application of chlorine prior to the addition of other chemicals (pre-chlorination) would be effective in reducing the false positive presumptives (Damann, 1950). The reduction has been found to be 70% when comparing the 74% reported by Jones in 1948 to the 1955 Lipousky data of 4%.

As a means of determining the species responsible for the false positive presumptives, more than 30 pure cultures were picked from nutrient agar plates for taxonomic study.

TABLE 1.—A Comparison of the Presumptive and Confirmed Results of Charleston, Illinois, Drinking Water Before and After Chlorination.

	Raw water (before chlorination)		Drinking water (after chlorination)	
	Number	Percent	Number	Percent
Portions tested	50	100	125	100
Portions presumptive in 48 hours	40	80	5	4
Portions confirmed in brilliant green bile	39	78	..	..
Portions false positive presumptives	1	2	5	4

The raw lake water selections yielded eight different species while only four species could be positively identified from the chlorinated drinking water (Table 2). The coliform species that indicate pollution, *Aerobacter aerogenes* and *Escherichia coli*, were encountered in the raw lake water isolations only. All of the *Bacillus* spp. reported (Table 2), except *B. polymyxa*, are considered to be widely distributed in nature in the water, soil, and dust. Thus, they are accorded little significance in matters of sanitation. *B. polymyxa* differed from the other species in that it fermented lactose, producing gas, but failed to confirm in brilliant green bile which marked it as a false positive presumptive.

To investigate the possibilities that a synergic reaction might also be responsible for false positive presumptives, each of the non-lactose fermenting species isolated from chlorinated water, *Bacillus cereus*, *Bacillus subtilis*, *Proteus mirabilis*, was inoculated into lactose broth in all possible combinations. Under none of the conditions could gas be produced in lactose broth unless *B. polymyxa* was also introduced. Thus, it appears evident that *B. polymyxa* must be responsible for the false positive presumptives in both the raw lake water and the chlorinated drinking water at Charleston, Illinois.

DISCUSSION

Specimens of *Bacillus polymyxa* have been found in both chlorinated and unchlorinated water in Maryland, Kentucky, Iowa, and in Illinois from Lake Michigan (Prescott, 1945: 82). Even though the species is common in soil from cultivated fields and pastures and has been found in abundance in decaying vegetables, its significance in drinking water has not been clearly determined. In the laboratory it has been found to produce the antibiotic polymxin.

Proteus mirabilis has been found in putrid meat, infusions, and in abscesses, which makes its appearance in the chlorinated drinking water a matter of concern. Cherry, Lentz, and Barnes (1946) reported this species as a possible cause of gastroenteritis, which definitely

TABLE 2.—Species of Bacteria Isolated from Lake Water Before and After Chlorination. September and October, 1955, Charleston, Illinois.

Lake water	Chlorinated water
Aerobacter aerogenes	none*
Bacillus brevis	none*
Bacillus cereus	Bacillus cereus
Bacillus coagulans	none*
Bacillus firmus	none*
Bacillus laterosporus	none*
Bacillus polymyxa	Bacillus polymyxa
none*	Bacillus subtilis
Escherichia coli	none*
none*	Proteus mirabilis

* Indicates that the corresponding species was not found.

makes its presence undesirable in drinking water. The fact that it was not found in the raw lake water but was found in the chlorinated drinking water suggests the possibility of secondary contamination in the distribution system occurring after the water had passed through the filtration treatment.

There is no direct evidence to support the view that *Proteus mirabilis* is a causative agent for any of the gastro-intestinal cases that occur in Charleston.

SUMMARY

A bacteriological investigation of the cause of the high percentage of false positive presumptive tests occurring in drinking water in Charleston, Illinois, was conducted during September and October, 1955. *Bacillus polymyxa* was isolated as the species responsible for the false positive presumptive results. *Proteus mirabilis*, which has been associated with gastroenteritis at a naval base in eastern United States, was also found in the chlorinated drinking water of Charleston, Illinois.

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ACADEMY BUSINESS

SECRETARY'S REPORT OF THE BUSINESS OF THE ILLINOIS STATE ACADEMY OF SCIENCE FOR THE YEAR MAY 7, 1955, TO MAY 5, 1956

Compiled by

LYLE E. BAMBER, *Secretary*

The 49th annual meetings of the Illinois State Academy of Science were held with the Illinois State Museum as host at Springfield, Illinois, on May 4 and 5, 1956. The programs of the ten sections included 97 papers, and total attendance at the section meetings was about 440 persons.

The general morning session of Friday, May 4, was held in the Auditorium, Centennial Building, and included the Welcome by Judge Vera M. Binks, Director of the Department of Registration and Education, and the Presidential Address by Dr. Shanor entitled "The Influence of Fungi in Human Affairs".

At 10:50 a.m. a symposium on "Management of Vegetation on Right-of-Ways" was conducted with Dr. Willard D. Klimstra as Convener. Those taking part were: Mr. T. N. Cofer, Overhead System Engineer, Central Illinois Public Service Company; Mr. Rockwell Smith, Research Engineer, Roadway Association of American Railroads; Mr. Albion Gries, Landscape Engineer, Illinois Division of Highways; and Dr. Harlow B. Mills, Chief, Illinois State Natural History Survey.

The Junior Academy program, under the capable direction of Miss Elnore Stoldt, had its usual wide appeal. There were about 800 projects on exhibit at the State Armory and more than 840 banquet tickets were sold. The Chicago schools took part this year for the first time. All districts increased in size; there being 206 clubs (70 new this year)

and approximately 8,000 members. A total of 3,127 students attended the district meetings. The Senior Academy members set aside the 11:30 a.m. time on the Friday program to visit the Junior Academy exhibits.

The annual banquet was held Friday evening in the ballroom, St. Nicholas Hotel.

The evening meeting was opened with the presentation of the winners in the Annual Science Talent Search by Dr. G. R. Yohe, Chairman of the Science Talent Search Committee. This year there were 20,828 examinations requested and 3,375 completed. Two hundred-fifteen of the completed were from Illinois. Of the 40 selected for the Washington trip, 3 were from Illinois, and of the 260 National Honorable Mentions, 23 were from Illinois. There were 14 additional State Honorable Mentions.

The annual public lecture was presented by Dr. Howard A. Meyerhoff, Executive Director, Scientific Manpower Commission, Washington, D.C., who spoke on "Scientists and the National Welfare".

Council Meetings

The Council held the usual four meetings during the year. The first meeting was held in the Life Science Building, Southern Illinois University, Carbondale, Illinois, on May 7, 1955.

Dr. Welch reported the registration of Senior members on Friday was approximately 350. Miss Stoldt reported there were about 500 exhibits at the Junior Academy and that some 540 persons attended the banquet. It was also decided to provide a suitable pin for the retiring student President of the Junior Academy.

Dr. Welch submitted the proposed budget for 1955-56 which was approved in an altered form. Dr. Welch was requested to continue as Treasurer until the return of Dr. James W. Neckers and his acceptance of his pro-tem appointment. The sum of $200 was approved to purchase Government Bonds to raise the permanent funds in Life Memberships to $1,400.

The following appointments were made: Dr. Glen S. Winterringer of Springfield was appointed Second Vice-President; Dr. James S. Ayars reappointed Publicity Advisor; Dr. Harvey I. Fisher was appointed Technical Editor in place of Jane S. Olson who resigned; and Dr. L. F. Audrieth and Dr. Paul C. Silva were selected as new members of the Publications Committee with terms to expire in 1958. Dr. Francis J. Kruidenier was nominated to fill the one year term on the Publications Committee left vacant by Dr. Fisher's new appointment.

Other business transacted included: establishment of the dates of the 49th Annual Meetings at Springfield as May 3 to 5, 1956; establishment of a Committee to revise the Constitution, with Dr. Ekblaw as chairman; appointment of a committee on the Academy sponsoring theme conferences and symposia, consisting of Wilbur W. Grimm as chairman, C. D. Proctor, W. W. Wantland, C. L. Kanatzar, and Edward L. Hill.

At the suggestion of Dr. Ekblaw a new standing committee was established to be called the State Research Conference Committee with Dr. Thiessen as chairman.

The second meeting of the Council was held in the Dome Room, Saint Nicholas Hotel, Springfield, Illinois, on November 12, 1955.

Miss Stoldt distributed copies of last spring's report and a new pamphlet financed by the Standard Oil Foundation. She reported a request to prepare a complete history of the Junior Academy which was approved; requested the purchase of a new file, also approved, and that next year's chairman be elected early in the year. The old question of National Science Fairs was discussed and a committee to assist in publicity of Junior Academy matters, especially in connection with the American Medical Association, was appointed by President Shanor with Dr. Ekblaw as chairman.

Dr. Winterringer, Second Vice-President, announced the St. Nicholas Hotel as headquarters for the next annual meetings. Other items under reports of committees were: 1) the consideration of a possible symposium on conservation in place of a guest speaker Friday morning of the meetings; 2) authorization of the preparation of a more elaborate brochure by the Membership Committee; and 3) approval of the Sustaining Membership Committee holding a special meeting of all sustaining members at the Springfield meeting.

Dr. Robertson requested that his resignation as A.A.A.S. delegate be held by the President until a suitable person could be selected to replace him and that the delegate be made an official

member of the Council and be appointed in January. The Council approved. The Council also approved the payment of first-class railroad fare for the Atlanta meeting of the A.A.A.S. delegate from the Sustaining Membership funds.

Two other motions approved were: 1) the fiscal year be established on a calendar year basis in the new constitutional revision; and 2) that student membership be abolished in the same revision.

Dr. Thiessen reported that the State Research Conference Committee had detailed plans drawn up for the conference to be held October 19-20, 1956.

The Third Council Meeting was held in the Wedgewood Room, Illini Union, Urbana, Illinois, on February 18, 1956.

President Shanor announced the following: 1) Dr. Howard A. Meyerhoff will be the evening guest speaker at Springfield; and 2) Governor Stratton will deliver the "Welcome".

Miss Stoldt reported: 1) that there are 150 clubs registered at present in the Junior Academy; 2) that some clubs associated with museums would like to join; and 3) that Elroy Smith is preparing a history of the Junior Academy. It was decided not to pay for a luncheon to be held for the judges at the Springfield meeting.

Dr. Neckers gave the Treasurer's report. The Council decided that "the Treasurer may deposit in one or more State approved interest paying financial institutions an amount approved by the Budget Committee".

Second Vice-President Winterringer gave plans for the Annual Meetings at Springfield with headquarters in the St. Nicholas Hotel. The Nature Conservancy noon luncheon on Friday was approved.

The editor, Dr. Fisher, requested approval of his "Instructions to Authors" for the *Transactions*. They were approved. It was also moved and passed that the Publications Committee consider a supplementary publication and refer the problem to the new Publications Committee for final action.

The Council requested the President to appoint a committee of botanists to study the original Fuller proposal to publish additions to the *Flora of Illinois* and report back to the Council.

Committee reports included: 1) needed changes in the budget presented by Dr. Neckers, and approved; 2) announcement of a symposium on conservation at the Friday morning general meeting at Springfield; and 3) presentation by Dr. Kanatzar of a program for Sustaining Members at the annual meetings.

Two general reports were made by the Committee on Symposia and Theme Conferences and the Committee on Proposal for an Undergraduate Research Conference. Copies of these reports are in the Secretary's files.

The fourth meeting of the Council was held Thursday evening, May 3, 1956, in the Green Room, St. Nicholas Hotel, Springfield, with Dr. Leland Shanor presiding. Dr. Glen S. Winterringer reported that local arrangements for both Senior and Junior academies were complete. Preliminary reports were presented by officers, committee chairmen, and section chairmen. Final reports were presented at the annual business meeting on Friday, May 4, 1956. These are included below.

Annual Business Meeting

The business meeting of the 49th annual meetings of the Illinois State Academy of Science was held May 4, 1956, in the Green Room, St. Nicholas Hotel, Springfield, at 5:00 p.m. with President Leland Shanor presiding.

The report of the Secretary, which follows, was seconded by Dr. R. A. Evers and accepted.

The minutes of the business meeting of the 48th annual meetings held at Southern Illinois University, Carbondale, have been published in the *Transactions*. They include deliberations and actions of the Council and various committees of the Academy, reports of the Treasurer, Auditing Committee, Nominating Committee, and the Resolutions Committee.

The major activities of the Council throughout the past year were summarized and mailed to each member along with the program for the 49th annual meetings in the form of the President's letter.

Mr. President, I move the acceptance of the report of the 48th annual meetings as published in the *Transactions* and the summary of the year's activities as included in the President's letter.

Dr. James W. Neckers presented the Treasurer's report which follows. He moved acceptance of the report. Dr. H. R. Wanless seconded the motion.

Dr. Harvey I. Fisher, Editor, reported that the *Transactions* would be out by June 1. Due to increase in cost it will be smaller in size. He suggested the

TREASURER'S REPORT

1955-56

Balance, April 30, 1955		$ 4,741.44
RECEIPTS		
Annual dues	$ 2,330.25	
Sustaining members	2,544.03	
Life memberships (permanent fund)	100.00	
Bequest of Dr. Ruth Marshall Estate	100.00	
Registrations at Carbondale	158.00	
Interest on investments	77.60	
A.A.A.S. research grants (contra)	345.00	
Goethe fellowship fund	100.00	
Total receipts		$ 5,754.88
TOTAL—balance and receipts		$ 10,496.32
EXPENDITURES		
Council	$ 224.61	
Secretary's office	830.71	
Treasurer's office	388.62	
Librarian	127.12	
Editor	5.73	
A.A.A.S. research grants (contra)	345.00	
Membership committee	623.24	
Science talent search committee	289.12	
Junior Academy	1,322.43	
Goethe fellowship	19.75	
To reserve fund	4,000.00	
		$ 8,176.33
DIFFERENCE		$ 2,319.99
Outstanding checks		295.59
CASH BALANCE in Carbondale National Bank, April 30, 1956		$ 2,615.58[1]
RESERVE FUND		
U. S. bonds	$ 1,800.00	
State Savings and Loan Assn., East St. Louis	4,000.00	
		$ 5,800.00
PERMANENT FUND		
Life memberships in		
U. S. bonds	$ 1,200.00	
Cash in Carbondale National Bank	300.00	
		$ 1,500.00

[1] Includes $300 in life membership permanent fund.

publication of a larger issue next year with support from the Academy treasury. Dr. W. W. Wantland moved that the report be accepted; motion seconded by Dr. Wilbur W. Grimm.

Reports of Standing Committees

Animal Experimentation in Research.—Dr. W. W. Wantland gave a brief summary report. Its work consisted of the following:

1. Continued efforts to present the objectives and results of animal experimentation in biological and medical science to the public through:
   a. classroom lectures and demonstrations.
   b. film presentations.
   c. talks to lay groups.
2. Keeping abreast of the development of new practices and regulations in connection with transportation of experimental animals.
3. Keeping abreast of newly developed practices for slaughtering stock animals for food.
4. Keeping abreast of new rules, regulations, and ordinances concerning the procurement of an adequate number of animals to be used in medical study and research.
5. Contacting physical scientists to acquaint them with objectives and values of animal experimentation and to ascertain their stand on the matter.

Dr. Grimm moved acceptance of the report. Dr. Proctor seconded.

Budget.—Dr. J. W. Neckers submitted the report which is to be acted on by the new Council. A copy is in the Secretary's files.

Conservation Committee.—Dr. Willard Klimstra reported it had no final results to present. However, some of its activities are in the form of a written report in the Secretary's files.

Living Memorials Committee.—Dr. George E. Ekblaw reported a large project of some 1000 acres and costing about one million dollars was nearing realization near Urbana.

Membership Committee.—Mr. G. H. Boewe reported that 95 members were dropped or resigned and 177 new members were added during the year. The total membership is about 1462. Mr. Boewe then moved that persons who have applied for membership during the past year and who have met the qualifications for membership be elected to membership. Dr. Thut seconded. The motion carried.

Research Grants Committee.—Dr. H. F. Thut mentioned the survey report on grants for the years 1950-1955 which was given out at the fourth council meeting. A copy is in the Secretary's files. This year four projects were chosen to receive grants but because of lack of funds the Committee could only partially cover the requests. The Committee requested that the Council provide the necessary added funds to make the grants 100%. Dr. Proctor so moved. Dr. Robertson seconded. Carried. The grants given in total were:

1. Dorothea S. Franzen, Illinois Wesleyan University, $100. Work on molluscan species.
2. Harold C. Fritts, Eastern Illinois State College, $140. Work on the radial growth of the white oak.
3. Sister Mary Marina, Mundelein College, $50. Work on the syntheses of 4-Dichloroquinoline, an antimalarial intermediate.
4. John W. Voigt, Southern Illinois University, $150. Work on forest ecology.

Reports of Special Committees

The report of the Auditing Committee was presented by Otis B. Young. He moved acceptance of the report which follows. Dr. Wanless seconded and the motion passed.

To whom it may concern:

This is to certify that the Auditing Committee has examined the financial accounts of the Treasurer of the Illinois State Academy of Science and has found them to be correct and to check with the statement of balance by the Carbondale National Bank. This audit was made as of April 30, 1956.

(signed)
Otis B. Young, *Chairman*
W. M. Gersbacher
S. E. Harris

The *Resolutions Committee* submitted six resolutions to the Academy. Dr. Paul R. Shaffer presented the report and the following resolutions were adopted by the Academy.

1. *Whereas*, the facilities provided and the arrangements and provisions for this 49th annual meeting of the Illinois State Academy of Science by its host, the Illinois State Museum, have contributed greatly to a successful meeting,

Be it resolved that the Academy express its gratitude to Mr. Glen S. Winterringer, Second Vice-President, who was in charge of local planning, to Mr. Thorne Deuel, Director of the Museum, for issuing the invitation for our meeting in Springfield, to Mr. Milton D. Thompson for his aid in providing facilities for the meeting, and

Be it further resolved that the following persons and organizations be commended for the aid indicated and that the Secretary be instructed to send a copy of this resolution to those named in it.

1. Mrs. Dixie Vincent and the entire stenographic staff of the Museum for their aid in the Junior Academy judging program.
2. The Museum Society for furnishing coffee and doughnuts at the judges' breakfast and for furnishing lunch for the judges.
3. The Association of Commerce and Industry — particularly the Convention Bureau and Miss Murphy, the Chairman of the Convention Committee, for arranging for housing and a multitude of other details.
4. Mr. Strother Jones, in charge of the Fairgrounds, for furnishing tables and labor for moving them for use of the Junior Academy.
5. Mr. Emmings, of the Springfield Park Board, for furnishing tables for the use of the Junior Academy.
6. To the Adjutant General of the Armory who made the Armory available for the use of the Junior Academy.
7. To Mr. Brown, Superintendent of the Armory, and his crew of workers at the Armory.
8. To Mr. Russell Hawkins, of Hawkins Electric, for a major contribution of time and costs of operations in connection with the Junior Academy exhibits.
9. To Mr. Bruce Wheeler, Assistant Superintendent of Schools, for making rooms available in the Old High School for Junior Academy meetings.
10. To Dean O'Laughlin, of Springfield Junior College, for arranging to furnish students for manning the projectors and running errands in connection with the Section meetings and to each of the students.
11. To Mr. Charles Harriett, Publicity Director of Illinois State Museum, for a publicity job well done.

2. *Whereas*, the Illinois State Museum has served the citizens of Illinois for more than 75 years as a highly valuable educational institution, and *Whereas*, Governor William G. Stratton has expressed concern over the present inadequate housing of the Museum and interest in providing new space,

Be it resolved, that the Illinois State Academy of Science commend Governor Stratton for his interest in obtaining new housing for the Museum.

3. *Whereas*, the natural resources of our State have been diminishing because of a lack of public interest, understanding and support, and *Whereas*, the Illinois Department of Conservation recognized its part in correcting this apathy by actively sponsoring a conservation education program for teachers, farmers, and school children through the Springfield Conservation Area Programs.

Be it resolved that the Illinois State Academy of Science commend the Department and its Director, Glen D. Palmer, for this action and that the Academy give its continued support.

4. *Whereas*, certain game species have been extinct in Illinois for many years because of destroyed habitat and lack of protection, and

Whereas, re-establishment of suitable environment now seems to be progressing satisfactorily towards providing the requirements of the wild turkey, ruffed grouse, and prairie chicken,

Be it resolved that the Illinois State Academy of Science commend and support the Illinois Department of Conservation and its Director, Glen D. Palmer, in a program attempting to re-establish native game species.

5. *Whereas*, the work of the Junior Academy of the Illinois State Academy of Science for the past two years has been a continuation and expansion of the excellent work of that group, and

Whereas, the Junior Academy has made a notable contribution in arousing the interest of young people in science and helping to train them in use of the scientific method,

6.

Be it resolved that the Academy highly commend the work of Miss Elnore Stoldt, Jacksonville High School, for the outstanding service to the young people of Illinois in her direction of the Junior Academy program and to Dr. C. L. Kanatzar for his direction in raising funds to carry on this outstanding endeavor, and

Be it further resolved, that the Academy recognize the encouragement and support given the Junior Academy program by Mr. John S. Aggar, Principal of Jacksonville High School, in the form of secretarial help and supplies.

6. *Whereas*, several members of the Academy have died during the past year,

Be it resolved that the Academy express its sympathy to the surviving family, and

Be it further resolved, that the Secretary is instructed to transmit a copy of this resolution to the nearest surviving relative. The list of deceased members is:

William Marshall Bailey
Gustav Egloff
Clarence George Fawcett
John H. Hauberg
Carl Leland Horberg
Hilton Ira Jones
Ruth Marshall
John E. McCorvie
Helen Miller Noyes
Gordon W. Raleigh
William Frederick Schulz
Kathryn M. Sturm
Emil Weiss
Will A. Whitney

(Signed)
E. L. Stover
Lyle Finley
M. D. Thompson
Paul R. Shaffer, *Chairman*

The *Nominating Committee* consisted of Harold R. Wanless, Chairman, Lyle E. Bamber, Kenneth E. Damann, E. L. Hill, C. W. Hudelson, and Willard Klimstra. Dr. Wanless presented a slate of officers for 1956-57 and a roster of committee chairmen and committee members. This list will be published in the program for the 50th annual meetings and later in the *Transactions*. Dr. Wanless moved the slate be accepted. Dr. White moved the slate be accepted and that the Secretary cast a unanimous ballot. Dr. Proctor seconded. Carried.

Dr. W. W. Grimm gave the report for the *Committee on Theme Conferences and Symposia*. This was a progress report indicating further study was needed. Dr. Ekblaw moved we accept the report. Dr. Boewe seconded. Carried.

President Shanor reported briefly for Dr. Thiessen, who was absent, for the *Committee on Proposal for an Undergraduate Research Conference*. The plans have not been accepted as yet by the National Science Foundation. Dr. Ekblaw moved we accept the report and commend the committee for its work. Dr. Proctor seconded. Carried.

Dr. R. A. Evers reported for the *Special Committee to Study the Proposal to Publish Additional Records to the "Vascular Plants of Illinois"*. The committee reported the Illinois State Museum has worked out a plan at no expense to the Academy which will be of more value to the collectors.

President Shanor announced that an invitation had been received to meet next year at Normal. Dr. Ekblaw moved we accept the invitation. Dr. Damann seconded. Carried.

President Shanor commended the officers for their services during the year.

Dr. Ekblaw moved that the officers be thanked by means of a standing vote. So carried.

The meeting adjourned.